CHAPTER 5
ELECTRONIC AIDS TO NAVIGATION:
TACAN, AN/SRN-6 (PART I)

INTRODUCTION

This chapter presents a complete block diagram discussion of the AN/SRN-6 Tacan System, and the circuit operation of the receiver system. In the block diagram discussion, particular emphasis is placed on the purpose and relationship of the component parts. In the discussion of the circuit operation of the receiver, emphasis is placed on the operation of each stage, and how it affects the remaining circuits of the receiver to produce the receiver output.

GENERAL DESCRIPTION

Radio Set AN/SRN-6 is used for shipboard installation to provide the radio beacon or ground portion of an air navigation system, called TACAN (Tactical Air Navigation). The AN/SRN-6, its associated antenna group and accessories, and Radio Set AN/ARN-21 (located in aircraft) make up a complete air navigation system. The beacon supplies information through which an aircraft equipped with an AN/ARN-21 can accurately determine its position. Figure 5-1 shows the major components of a shipboard radio beacon.

The AN/SRN-6 comprises three major groups: receiver-transmitter, antenna, and power supply test set. The specific functions of these equipments will be discussed in detail later.

As many as 100 aircraft may simultaneously obtain navigational information in conjunction with a single installation of the AN/SRN-6. The set is capable of receiving on any one of 126 frequencies (channels) in the range of 1025 to 1150 mc. Transmission of information also takes place on 126 channel frequencies in the ranges of 962 to 1024 mc and 1151 to 1213 mc.

Two types of antennas are available for use. Each antenna operates on 63 channels, corresponding to low-band frequencies and high-band frequencies, respectively. Low-band installations transmit at frequencies between 962 and 1024 mc inclusive, and receive at frequencies

between 1025 and 1087 mc. High-band installations transmit in the range of 1151 to 1213 mc, and receive in the range of 1088 to 1150 mc.
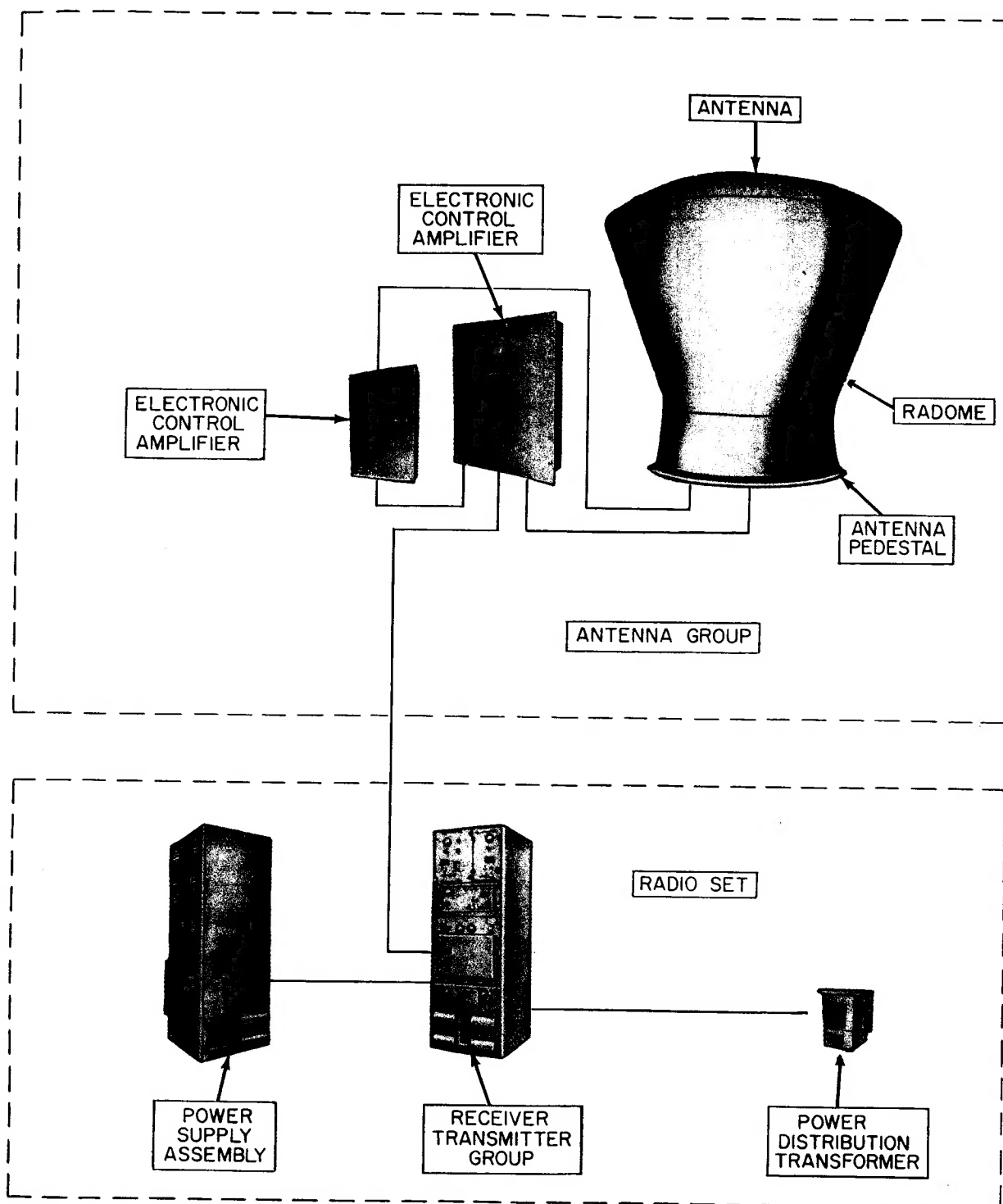
Two frequencies are used in each channel: one for receiving, and one for transmitting. The frequency used for receiving in low-band installations is 63 mc above the frequency used for transmitting in the same channel. In high-band installations, the receiving frequency is 63 mc below the transmitting frequency.

The Radio Beacon AN/SRN-6 output consists of the bearing information signals, the beacon identification code, distance information signals, and random pulses used to make up a constant duty cycle. The radio beacon periodically transmits its identifying call in International Morse Code, thus enabling the interrogating aircraft to determine the radio beacon with which it is in contact. The characters of the code consists of a train of pulse-pairs generated at a fixed rate of 2700 pulse-pairs per second. During the transmission of the code, the 2700 pulse-pairs are grouped so that the reproduced tone will be at a frequency of 1350 caps. A motor-driven mechanical keyer in the coder-indicator accomplishes the coding. The aircraft receiver detects these regularly occurring pulse-pairs and reproduces the code as a keyed 1350-cps audio tone.

The bearing information reference burst (discussed later) has priority over the identification call. The identification call has priority over the distance information signals. The relative duration of these signals is such that there is, effectively, no interruption of distance information or identification call.

When the radio beacon is in operation, reference burst information will be transmitted at regulated intervals. The beacon identification code signals will be transmitted every 37.5 seconds. Any airborne Radio Set AN/ARN-21, which is tuned to the beacon radio frequency, will receive the reference burst and identification signals.
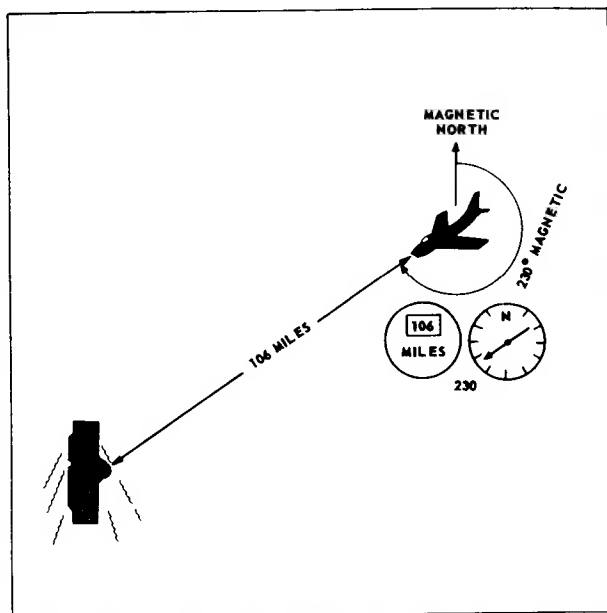
The aircraft radio set transmits distance interrogation signals only and receives replies

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ANTENNA

ELECTRONIC
CONTROL
AMPLIFIER

ELECTRONIC
CONTROL
AMPLIFIER

RADOME

ANTENNA
PEDESTAL

ANTENNA GROUP

RADIO SET

POWER
SUPPLY
ASSEMBLY

RECEIVER
TRANSMITTER
GROUP

POWER
DISTRIBUTION
TRANSFORMER

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Figure 5-1.—Major components of Radio Beacon, AN/SRN-6.

from the radio beacon. Under normal circum-
stances, the range over which aircraft can ob-
tain reliable distance information from the
beacon is about 200 miles. The received infor-
mation is presented as polar coordinate data
(fig. 5-2), having both distance (in nautical
miles) and azimuth (in degrees of magnetic
bearing) of the aircraft from the radio beacon.

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Figure 5-2.—Polar coordinate presentation
of Tacan Data.

The aircraft radio set transmits pairs of
pulses on the assigned channel. The pulses of
each pair are spaced 12 μs apart. The radio
beacon receives the distance interrogation
pulse-pairs, and in reply, transmits back to the
aircraft pulse-pairs on the assigned channel.

The time delay between the distance interro-
gation pulse-pair (transmitted from the aircraft)
and the corresponding distance pulse-pair reply
(transmitted from the radio beacon) is adjusted
at the radio beacon to exactly 50 μs. The air-
craft radio set deducts 50 μs from the total
time elapsed between the interrogation and re-
ply. The distance between the aircraft and the
radio beacon is determined by measuring the
total time elapsed between initial transmission
of the distance interrogation pulse-pair and the
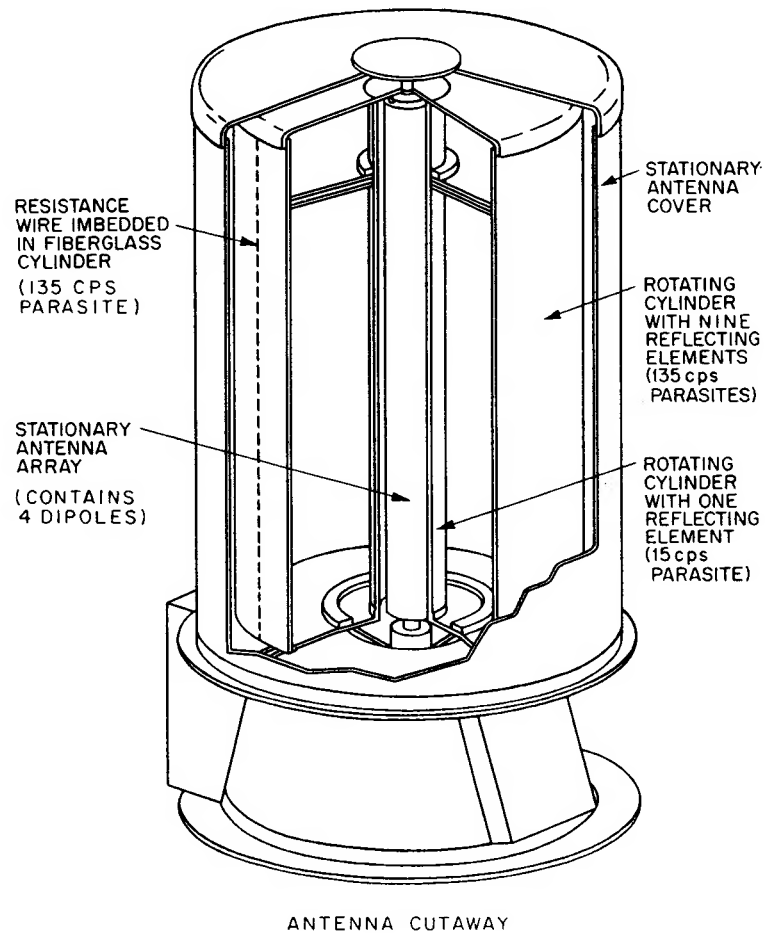reception of the corresponding radio beacon
reply.

The pulse-pairs sent by the AN/ARN-21
(aircraft equipment) are transmitted on a

carrier frequency which is the same as that of
the radio beacon. The pulse-pairs are trans-
mitted at a random rate peculiar to the AN/
ARN-21 aboard a specific aircraft. When re-
ceiving, the AN/ARN-21 selects its own partic-
ular distance-measuring reply from all other
signals by comparing the repetition rate of the
reply pulses with the repetition rate of those
originally transmitted. The receiver locks in
on the reply pulses whose repetition rate is the
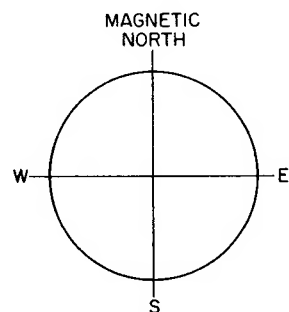same as the rate of its interrogation pulses.

The radio beacon operates on an assigned
crystal-controlled carrier frequency. As stated
earlier, as many as 100 aircraft can simulta-
neously interrogate the beacon on its single
channel frequency. It is quite possible that two
aircraft may interrogate at the same time and
with the same pulse rate. If this does occur,
each of the aircraft may receive conflicting in-
formation. However, the chances of such an
occurrence are highly improbable.

Bearing information originates from the an-
tenna in the radio beacon. A single stationary
vertical antenna (fig. 5-3, A) provides an omni-
directional pattern, such as shown in figure
5-3, B. A 15-cps parasitic element is properly
spaced from the antenna so as to deflect the r-f
energy to produce the cardioid pattern of figure
5-3, C. The parasitic element is motor driven
so that it encircles the antenna at a rate of 15
revolutions per second. Thus, the parasitic
element of the antenna modulates the total radio
beacon output with a subaudio (15 cps) frequency
component.

Mounted concentrically with the 15-cps an-
tenna element is an arrangement of nine vertical
reflectors embedded in an outer fiberglass cyl-
inder, which rotates simultaneously with the
inner cylinder at the 15-rps rate. Mechanically
linked to each of the rotating cylinders, and
mounted horizontally below the central array is
an assembly referred to as the pulser plate
(fig. 5-4, A). On the upper edge of the pulser
plate (fig. 5-4, B) there is one soft iron slug.
On the lower edge of the circular plate there
are eight similar slugs. As the pulser plate
rotates, the upper and lower slugs of the plate
pass through air gaps of pickup coils. As the
slug passes through the air gap of the pickup
coil, the net reluctance of the magnetic circuit
changes, and a pulse is induced in the coil wind-
ing. One coil is excited by the upper slug (15
cps) once for each revolution. A second coil is
excited by each one of the eight lower (auxiliary)
slugs, in turn, at 40° intervals, except for one
80° interval when the space is occupied by the
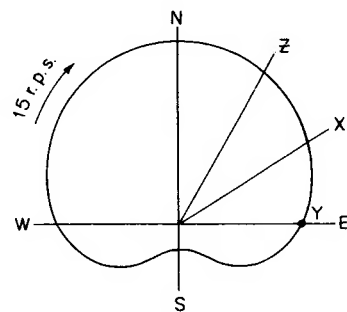pulse from the upper slug. The pulse from the

RESISTANCE
WIRE IMBEDDED
IN FIBERGLASS
CYLINDER
(135 CPS
PARASITE)

STATIONARY
ANTENNA
COVER

ROTATING
CYLINDER
WITH NINE
REFLECTING
ELEMENTS
(135 cps
PARASITES)

STATIONARY
ANTENNA
ARRAY

(CONTAINS
4 DIPOLES)

ROTATING
CYLINDER
WITH ONE
REFLECTING
ELEMENT
(15 cps
PARASITE)

ANTENNA CUTAWAY

A

MAGNETIC
NORTH

EQUAL FIELD STRENGTH PATTERN
AT CENTER RADIATOR

B

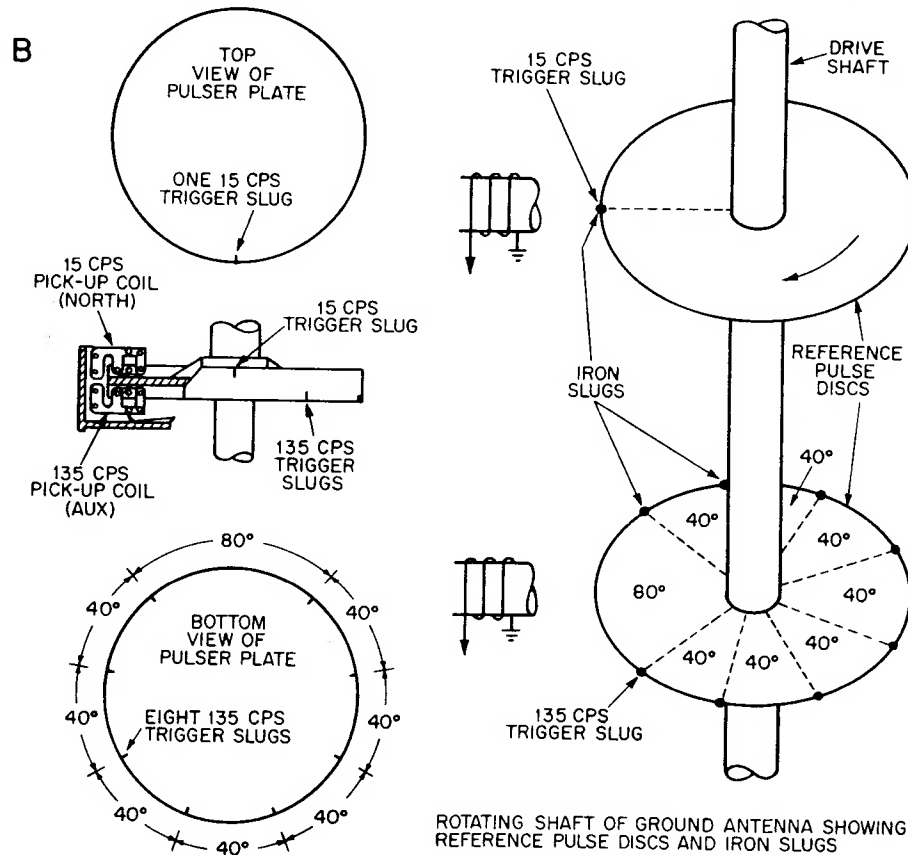CARDIOID FIELD STRENGTH PATTERN
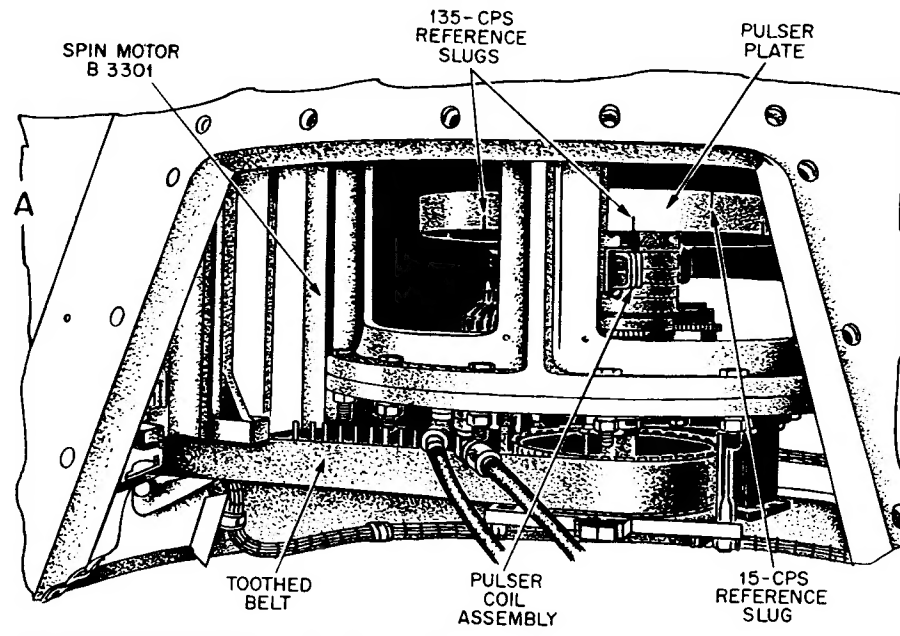CREATED BY SINGLE PARASITIC

C

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A. Construction of antenna and antenna parts.
B. Equal field strength pattern of center radiator.
C. Cardioid field strength pattern created by single parasitic.

Figure 5-3.—Antenna construction and antenna patterns.

A. Method of generating reference pulses.
B. Reference burst pulser plate.

Figure 5-4.—Reference burst pulser assembly.

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upper slug occurs at a time between the eighth and first pulse of the outer cylinder. As a result of the spacing of the 8 auxiliary slugs, only 8 pulses per cycle of rotation will be generated, but at a recurrence rate of 9 pulses per cycle. Hence, the rate of the auxiliary pulses is 9×15 or 135 pulses per second.

The pulse produced by the upper slug on the pulser plate is used to establish magnetic north as a reference point in time. The pulse triggers the generation of a coded burst, each pulse of which triggers the transmitter r-f output from the beacon antenna. As stated above, the 15-cps pulse is generated once during each revolution of the reflector. The pulser plate causes the generation of the 15-cps trigger pulse each time the peak of the radiation lobe points due east (an arbitrary point). The pulse thus obtained causes the generation of the north reference burst.

The aircraft receiver utilizes the 15-cps and the 135-cps modulation on the total received signal (and the 15-cps and the 135-cps reference bursts, which are also components of the received signal) in presenting azimuth information. Figure 5-5 shows the position of the north reference burst on the 15-cps sine wave (detected from the a-m, r-f carrier) as seen by four aircraft at four different points around the radio beacon. Figure 5-5, A, shows the position of the north reference burst on the 15-cps modulation for an aircraft due south (magnetic) of the beacon.

To understand this action, first consider the direction of rotation of the pattern and the signal components that the aircraft will receive. The pattern is rotating in a clockwise direction. With the pattern as shown at A, the aircraft will receive a portion of the total signal strength, which is neither maximum nor minimum. If the plane were repositioned to a point "a" minimum signal strength would be received. At "b" the signal strength received is again neither maximum nor minimum. In the latter case, however, the signal strength would be moving in the negative direction because the positions immediately following that (shown at "a") would yield even a smaller signal amplitude at the aircraft. At "c" an aircraft would receive maximum signal strength from the radio beacon. Thus, the signal received by the aircraft appears as a 15-cps sine wave with the position of the beacon represented by a vertical line (north burst) at some point along the X axis. The position of the waveform with respect to the vertical line varies with the aircraft position. The north reference burst always

occurs when the cardioid pattern points due east.

PHASE OF 15 CPS REFERENCED TO NORTH REFERENCE BURST FOR   AIRCRAFT SOUTH OF BEACON. BEACON BEARS 000° FROM THE PLANE

PHASE OF 15 CPS REFERENCED TO NORTH REFERENCE BURST FOR   AIRCRAFT WEST OF BEACON. BEACON BEARS 090° FROM THE PLANE.

PHASE OF 15 CPS REFERENCED TO NORTH REFERENCE BURST FOR   AIRCRAFT NORTH OF BEACON. BEACON BEARS 180° FROM THE PLANE

PHASE OF 15 CPS REFERENCED TO NORTH REFERENCE BURST FOR   AIRCRAFT EAST OF BEACON. BEACON BEARS 270° FROM THE PLANE
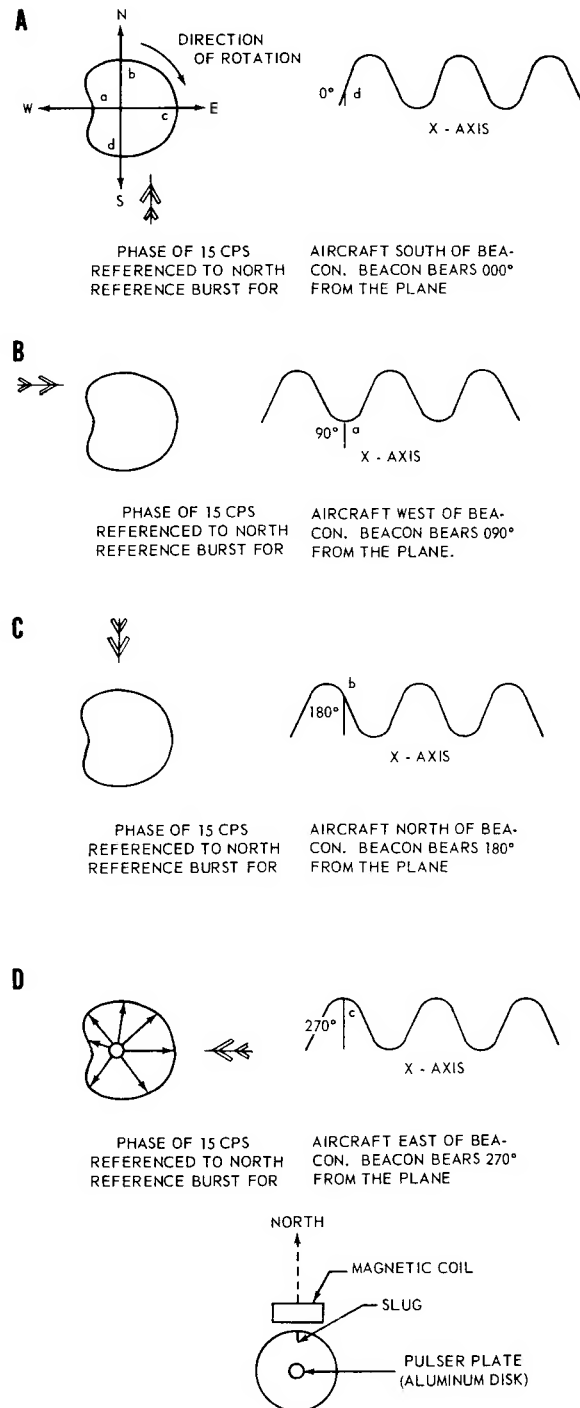
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Figure 5-5.—Relative positions of north reference burst.

In figure 5-5, B, the aircraft is receiving minimum signal amplitude at the time of the north reference burst. The ground radio beacon bears 090° (magnetic) from the aircraft. In figure 5-5, C, the aircraft is approaching the beacon from a point due (magnetic) north. The signal received by the aircraft would be half amplitude (on the 15-cps sine wave) and moving to the negative portion of the wave. The magnetic bearing of the beacon from the aircraft is therefore 180 degrees. In figure 5-5, D, the aircraft is approaching from due east, and receiving maximum signal strength from the radio beacon. The north reference burst would therefore appear at the maximum point on the receiver sine wave, indicating that the beacon bears 270° magnetic.

The time difference between the reference point on the 15-cps sine wave and the north reference burst is detected by the aircraft receiver of Radio Set AN/ARN-21 and converted to a meter reading in degrees, showing the bearing from the aircraft to the beacon with respect to magnetic north. Aircraft measures bearing from north reference point to the next positive-going half amplitude point of the modulation envelope. Figure 5-6 illustrates the signal received by four aircraft (in their respective positions as the beacon signal rotates through 360°) and the meter readings that would correspond to their particular bearings. Note that all the aircraft receive the north reference burst at the same instant of time but at a different phase of the 15-cps a-m wave.

The 135-cps amplitude modulation is provided to improve the bearing accuracy. This signal is also imposed on the r-f energy radiated by the radio beacon antenna. As stated earlier, the 135-cps signal is generated in the same method as the 15-cps component, with its directors spaced 40° apart around the radiating elements, and rotating about the antenna at a 15-rps rate.

The 135-cps signal alters the cardioid pattern to form a new pattern, as shown in figure 5-7. Thus, the antenna pattern basically consists of a large lobe (from the 15-cps director) and 9 smaller lobes (produced by the 135-cps directors).

Figure 5-8 summarizes the steps involved in the development of the composite 15-cps and 135-cps signal elements into the total bearing information supplied by the radio beacon to the aircraft. The signals, including the 15-cps and the 135-cps amplitude modulation and the 15-cps and the 135-cps reference bursts, received by the aircraft in the positions due east, south, west, and north of the beacon, appear as shown. Again, the phase of the modulation relative to the burst depends on the position of the aircraft with respect to the beacon. The 135-cps reference bursts are used to refine or make more accurate the measurement of the bearing relative to magnetic north.

The total radio beacon output consists of the internally generated reference-frequency modulated or keyed by pulse-pairs. The pulse-pairs are transmitted at a rate of 3600
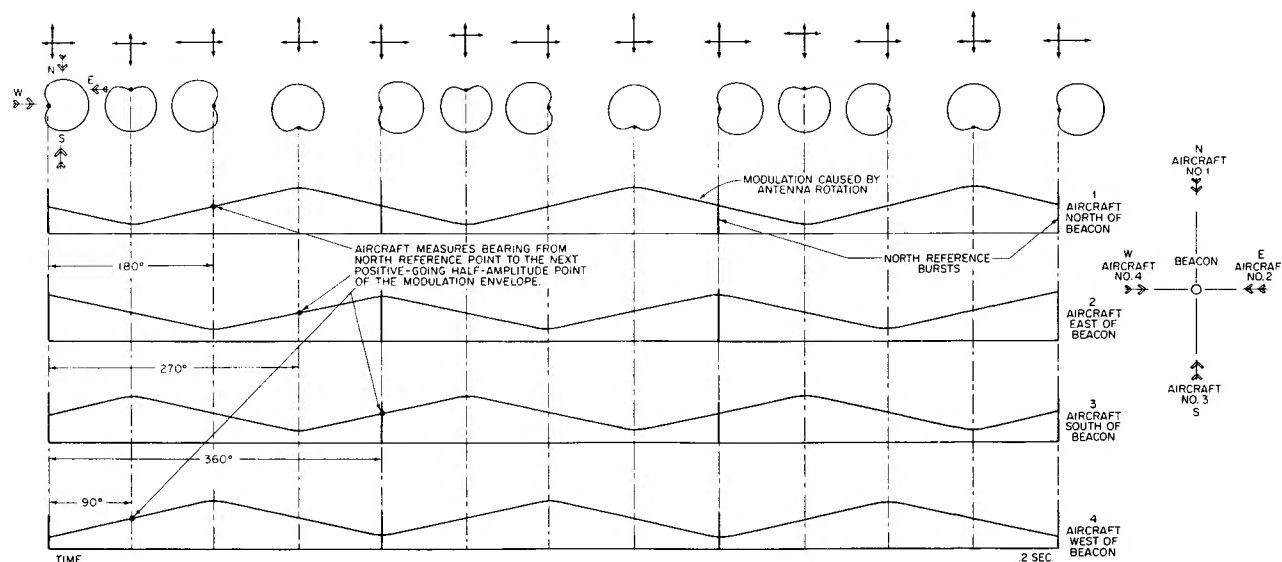

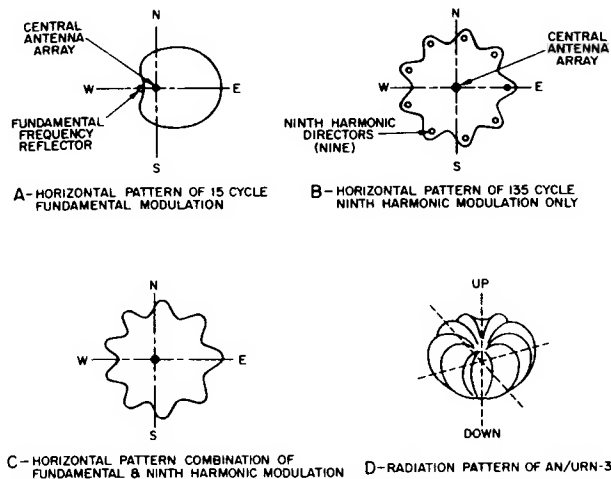Figure 5-6.—Meter readings for various aircraft positions.

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Figure 5-7.—Effects of 15-cps and
135-cps modulation.

pulse-pairs per second. Nine hundred of the
total pulse-pairs per second are the 15-cps and
the 135-cps reference bursts. (The reference
bursts are initiated by the 15-cps and 135-cps
trigger pulses.) The additional 2700 pulse-
pairs are either identification code distance
reply pulses or random squitter pulses gen-
erated to maintain a constant duty cycle.

The composite radio beacon pattern is
shown in figure 5-9. In 1/15 second (1 cycle of
15-cps signal), 12 north reference burst pulse-
pairs occur. Over a one-second period, 12 ×
15 pulse-pairs occur, which total 180 north ref-
erence bursts per second. Seven hundred and
twenty auxiliary (135 cps) reference burst
pulse-pairs occur each second. These pairs
are divided into 6 pulse-pairs occurring 120
times per second (8 times per cycle). Random
pulse-pairs (totaling 2700 pulse-pairs) are in-
serted between the reference bursts. Identity
pulse-pairs are substituted for the random
pulse-pairs once every 37.5 seconds.

Of the signals transmitted by the radio bea-
con, all except distance-measuring information
are initiated within the beacon. Distance reply
signals are supplied by the radio beacon only
when interrogated by the airborne radio set.
The AN/ARN-21 sends out a sequence of paired
pulses at a frequency of the radio beacon re-
ceiver and at a random rate peculiar to the par-
ticular equipment. This signal is received by
the radio beacon receiver and re-transmitted
to the aircraft, as described earlier. All sig-
nals transmitted by the radio beacon are char-
acterized by the fact that they consist of pulse-
pairs, with 12-μs spacing between the two

pulses of the pair. The number of pulse-pairs
per second and the spacing between the pulse-
pairs (the spacing between the leading edge of
the first pulse-pair and the leading edge of the
first pulse of the next pair) depend upon the par-
ticular signal element and is a characteristic of
that particular signal only. However, it is the
spacing of 12 μs between the pulses of a pair
which provides the aircraft radio set with the
means of distinguishing between the signal pulses
from the radio beacon and other pulses that may
be present on the received radio frequency.

The three elements of information (bearing,
identification call, and distance-measuring in-
formation) are transmitted by the radio beacon
as a train of pulse-pairs. To prevent interfer-
ence between the three signal elements, the ra-
dio beacon is equipped to assign a sequence of
priority by which each element enters into the
overall pulse train.

First in order of priority are the bearing
reference bursts. Because they occur at a fixed
rate, they are of relatively short duration and
convey the most important portion of the infor-
mation supplied by the beacon. Accordingly,
reference bursts will be transmitted regardless
of the number of interrogations.

Second in order of priority is the identity
call signal. The identity call signal also occurs
at a fixed rate. However, the duration of the
identity call is sufficiently long, so that the uti-
lization of the portion of the total duty cycle re-
quired for the insertion of the bearing reference
burst does not materially affect the reception
of intelligible identity code by the aircraft.

Third in order of priority is the distance in-
formation signal. The interrogation pulses are
not initiated within the beacon, and their arrival
within the pulse train must be controlled to pre-
vent their interfering with the other signal ele-
ments of the radio beacon. This is done by al-
lowing the interrogation pulses to enter the pulse
train only during a time interval not occupied
by the reference burst or the identity call sig-
nals. The period of the reference burst pulse is
small in comparison to the time between pulses
of the bursts. A memory circuit built into the
aircraft receiver makes it possible to compen-
sate for the time interval occupied by the iden-
tity pulses so that no apparent interruption of
distance-measuring signals results.

Last in order of priority are "squitter" pulses
consisting of random noise pulses, which are
used as fill-in signals when the maximum num-
ber of aircraft are not interrogating the beacon.
This is necessary to maintain the modulation
pattern and to permit a constant duty cycle.
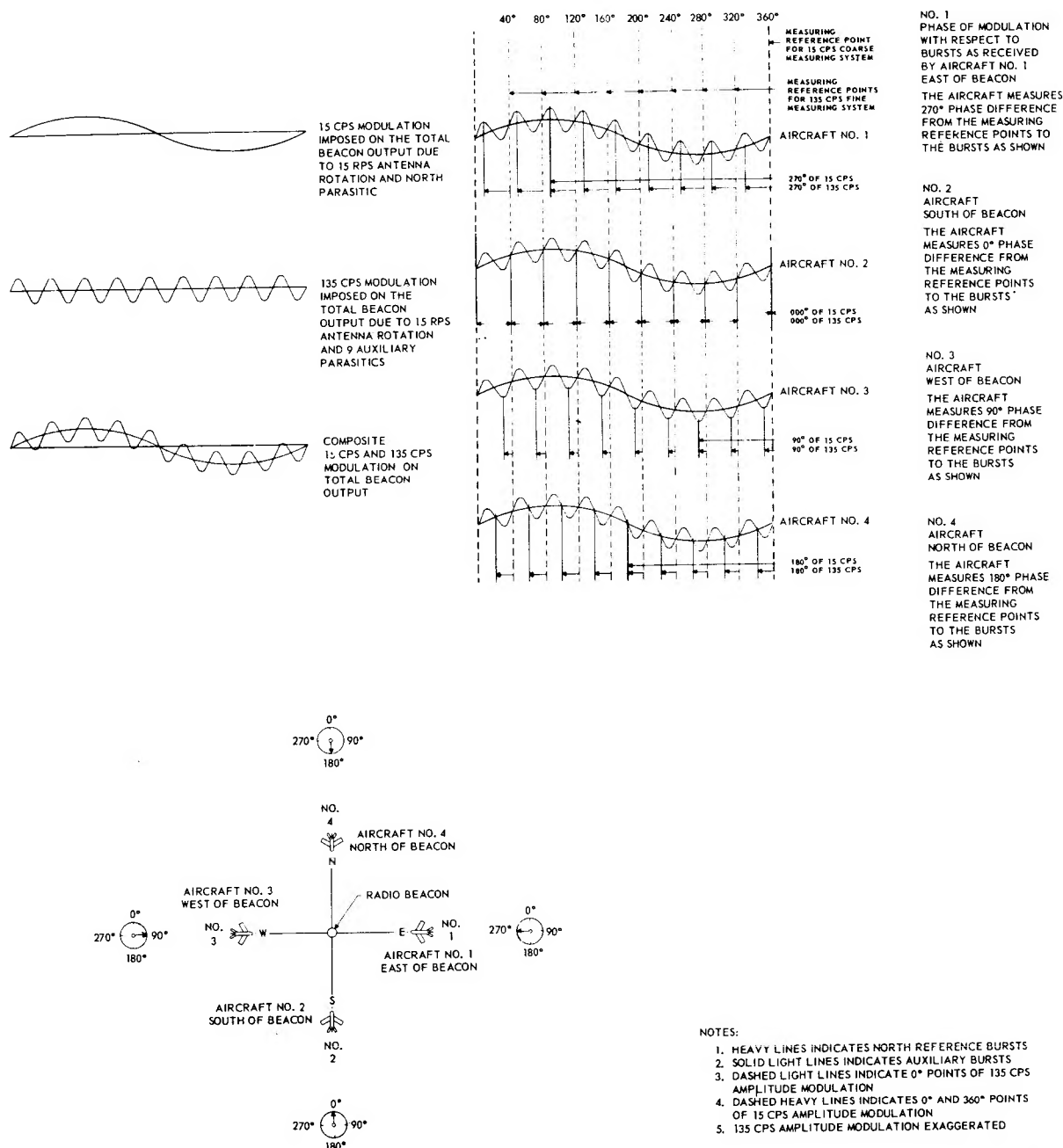
Figure 5-8.—Converting 15-cps and 135-cps amplitude modulation and burst signal
elements into bearing information.

BLOCK DIAGRAM

The functional arrangement of the major
units of the radio beacon is illustrated in fig-
ure 5-10. Pertinent waveforms are shown at
the input and output of the stages to aid in un-
derstanding the overall system operation.

RECEIVER

The antenna receives distance information
pulse-pairs from the aircraft and transmits
back to the aircraft the total beacon signal, in-
cluding the distance-measuring reply pulse-
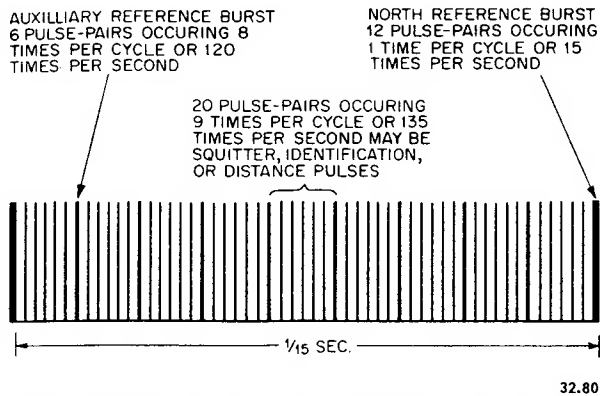pairs. The antenna also generates north and

Figure 5-9.—Composite radio beacon signal.

auxiliary trigger pulses at rates of 15 and 135 pps, respectively. These trigger pulses are generated in separate pulser coils, as described earlier (fig. 5-4). The 15- and 135-pps antenna trigger pulses initiate the generation of bearing information.

A single antenna is used for both transmission and reception. This is made possible through the use of the control duplexer. Distance interrogation pulse-pairs are received by the antenna and passed through a coaxial switch (fig. 5-10), along a coaxial line, and through the control duplexer to the radio receiver. In the receiver, the received signal passes through a low-pass filter, Z501, to the hybrid mixer stage of the receiver. The low-pass filter, Z501, rejects frequencies between 1,650 and 10,000 mc to prevent interference from other pulse-producing equipments operating in or near the beacon frequency range.

The local oscillator signal for the mixer stage is derived from the frequency-multiplier section of the radio beacon. The basic local oscillator frequency is generated in a crystal oscillator and doubler stage V1501. The oscillator-doubler, V1501, output is further multiplied in three stages of frequency multiplication which include the second doubler, V1502, the third doubler, V1503, and a tripler stage, V1504. The tripler, V1504, output is applied simultaneously to a keyed r-f amplifier, V1505 (discussed later), and to the mixer stage in the receiver. The heterodyning process in the mixer produces a 63-mc intermediate frequency signal.

The mixer output is amplified in three stages of preamplification comprising V201, V202, and V203. The V203 output is subsequently amplified in two stages of i-f amplification comprising V301 and V302, and further amplified in i-f

stages V303 thru V305 to a level sufficient to drive the Ferris discriminator, V306.

The Ferris discriminator, V306, detects the interrogation and random noise pulses from the 63-mc i-f signal, and effects adjacent and near-adjacent channel rejection.

The video signal output of the Ferris discriminator, V306, is fed to video amplifier, V307, and subsequently to video amplifier, V402A. An echo suppression circuit comprising V308A and V308B operate to remove undesired portions of the received signal. This circuit permits operation of the beacon equipment in areas where large reflecting objects (which cause reflected signals) are present.

The video output of V402A is applied to a blanking gate stage, V401. During the transmission of output pulses by the transmitter of the beacon, a 10-μs pulse generated in the frequency multiplier-oscillator video chassis is applied via J506 to the blanking gate stage. This pulse disables the receiver for the duration of the transmission.

The output of the blanking gate stage, V401, is amplified in video amplifier, V402B, and fed to a coincidence decoder circuit, V403. The decoder produces a single pulse for each input pulse-pair which has the pulses of the pair separated by 12 microseconds. The decoding of each pulse-pair is followed by a 40-μs blanking condition in the receiver to ensure that the 2700 pulses at the receiver output will be distributed over a period of one second. The delay line, DL401, ensures the generation of one pulse for each input pulse-pair.

The pulse output of the coincidence decoder triggers a one-shot multivibrator, V404, causing the multivibrator to produce three outputs. One output is used to initiate the blanking-gate pulse in the blanking-gate generator, V406. This action is described later. A second output from the one-shot multivibrator, V404, is fed to the receiver output cathode follower, V405. The V405 output serves as the receiver output, which is applied to the coder-indicator chassis.

The third output of the one-shot multivibrator, V404, is applied to a pulse amplifier, V408. Pulse amplifier, V408, pulse-counter, V409V, d-c regulator, V407A, and d-c clamp stage, V409A, are included in a circuit referred to as a "squitter control circuit." This circuit produces a negative (squitter) voltage which is fed back to the i-f amplifiers, V301 and V302. The squitter voltage controls the gain of the i-f stages so that the decoding of 12-μs interval pulse-pairs (interrogation pulses) and of random noise pulses generated in the receiver

tubes result in the desired output of 2700 pulses per second.

When the rate of the interrogation pulses plus the random noise pulses generated in the receiver tends to fall below 2700 pulse-pairs per second, the squitter voltage fed from V409A to the i-f amplifiers, V301 and V302, permits i-f amplification to be increased until a sufficient number of random noise pulse-pairs are decoded to maintain the receiver at the required rate. If the total number of receiver output pulses tends to rise above the set rate of 2700 pulse-pairs per second, the squitter control voltage from V409A causes the i-f amplification in V301 and V302 to be decreased. Thus, in effect, the total number of random noise pulses which are sufficiently large to trigger the coincidence decoder, V403, and to be fed through the one-shot multivibrator, V404, and through the cathode follower, V405, to the receiver output, are decreased.

Although the squitter-control voltage serves to maintain the receiver output at 2700 pulse-pairs per second, the entire pulse output could occur, for example, during the first quarter-second. Likewise, the entire pulse output in the following second could occur during the second quarter-second. A period of 1 1/2 seconds would be left during which there would be no output from the receiver. To prevent this action, the blanking gate stage, V401, is used to introduce a blanking period of 40 μs after the decoding of each pulse-pair. Since the receiver output pulse width from V405 is approximately 3 μs, the minimum spacing between the leading edge of one pulse from the receiver and the leading edge of the next is 65 μs, or the sum of the 40-μs blanking period, the coding time of 12 μs, the 10-μs blanking pulse from the transmitter, and the 3-μs duration of the receiver output pulse.

CODER-INDICATOR

The coder-indicator produces a multiplexed output signal which consists of three components: (1) the reference bursts; (2) the beacon identification call tone pulses; and (3) the distance reply pulses. Generation of the reference burst component has priority over the generation of all other output components.

The reference burst trigger pulses from the antenna pulser-plate (fig. 5-4) are applied to J903 and J904 (fig. 5-10). For each revolution of the antenna, the 135-cps reference burst generator receives 8 trigger pulses, and the 15-cps reference burst generator receives one 15-cps trigger pulse. The 135-cps trigger pulse, after being amplified in the 135-cps amplifier, V601A, is applied to the 135-cps reference burst gate generator, V609. For each pulse received at the V609 input, V609 produces an output pulse 150 μs wide. This pulse gates the pulsed oscillator, V610, to cause the generation of 6 pulses spaced 24 μs apart.

The 15-cps reference pulses are generated in a similar manner in the 15-cps reference burst circuit (V601B, V602, and V603). The output of the 15-cps pulsed oscillator, V603, consists of 12 pulses spaced 30 μs apart.

The output of the 15-cps and 135-cps pulsed oscillator (V603 and V610, respectively) is mixed in amplifier, V604A. From this point on, both pulse groups pass through the same stages. This action is possible because the two reference pulse groups never appear simultaneously.

The 604A output is applied to a one-shot multivibrator, V605. The stages consisting of multivibrator, V605, and triggered blocking oscillator, V606, are referred to as the "shaping amplifiers."

One-shot multivibrator, V605, receives interrogation signal pulses from the priority gate stage, V611, and the reference burst pulses from the amplifier, V604A. The action of V605 is to ensure proper spacing and amplitude of the pulses. The priority gate stage, V611, establishes the order by which the three-components of the total beacon signal are transmitted. The stage permits only one component of the signal to trigger V605 (and thus be transmitted from the beacon) at a given time.

The output of the multivibrator, V605, is applied to the blocking oscillator stage, V606. The purpose of V606 is to produce a sharp pulse (approximately 500 volts peak) which is capable of driving the encoding delay line, DL601.

The encoding delay line, DL601, is inductively tapped at 32-μs delay and 44-μs delay (12-μs delay between taps). The line introduces the major portion of the standard zero distance delay (50 μs) for distance reply pulses, and provides a pulse-pair which has a 12-μs spacing between pulses of a pair for each pulse fed into the delay line.

The double-pulsed output of DL601 is coupled to the output stages comprising V607A, V615, and V607B. These stages provide gain in the signal amplitude, improve the waveshape and uniformity of the output, and match the coder-indicator output impedance to the input impedance of the transmitter.

The path just considered through the coder-indicator was primarily that of the reference

burst signals. As might be expected, the path of the other components of the coder-indicator signal (namely, the distance reply pulses and the identification code tone pulses) differs considerably. Selection of one or the other of these components is controlled by the mechanical switching action of the identification call mechanical keyer (discussed presently).

The identification call tone of 1350 cps is generated by oscillator, V612. The oscillator is synchronized by a pulse obtained from the 135-cps reference burst gate generator, V609. The output from the oscillator, V612, is amplified in V613A and applied to a 100 μs multivibrator, V614. The output from the multivibrator, V614, for each pulse input from V613A, is a pair of pulses, each pair of which is separated by 740 μs, with the pulses in each pair separated by 100 μs.

Without the action of the 100 μs multivibrator to produce a pulse-pair from each pulse of the 1350-cps oscillator pulses, the total number of pulses transmitted from the beacon during the time that the identification code is being transmitted would be decreased from the required number of 2700 pulses per second. However, the double-pulsing action of the 100 μs multivibrator maintains the required pulse rate, while simultaneously preserving the 1350-cps tone in spacing (740 μs) between the pulse-pairs.

The output signal from the 100 μs multivibrator, V614, is applied to an identification code keyer stage, V613B. When the identification call keyer, A602, is allowing a ground to be placed on the diode plate (corresponding to a key-up-condition) the diode, CR603, acts as a low impedance path, and the 1350-cps signal is not passed through V613B. When the ground is removed (corresponding to a key-down condition) the diode (CR603) will not bypass the tone signal, but will allow it to pass through V613B to the priority gate stage, V611.

A gate blocked keyed amplifier, V604B, normally passes distance reply pulses from the receiver to the priority gate stage, V611. During the transmission of the identification code characters, a code keying wheel, A602, causes a -50 volt blocking gate to cut off the gate blocked distance reply amplifier, V604B. Simultaneously, the -50 volt gate keys the normally cutoff 1350-cps tone signal and permits the tone output to be sent to the priority gate stage, V611, as discussed. In this manner, the code keying wheel, A602, controls the selection of the code and establishes the priority of the

1350-cps tone signal over the distance reply signals.

The priority gate stage, V611, passes the identification code and distance reply signals to the shaping amplifiers, V605 and V606. Whenever a reference burst is generated, a blocking pulse from the mixing network at the output of the 15-cps and 135-cps reference burst gate generators (V602 and V609, respectively) is applied to the priority gate stage, V611. This pulse disables the priority gate stage for the distance reply and identification code pulses, but allows the reference burst pulses to pass. In this manner, the priority gate stage, V611, establishes the priority of the reference burst signals over the other signal components.

All signals from the priority gate stage, V611, to the shaping amplifiers, V605 and V606, are shaped, double-encoded, amplified, and sent to the transmitter as components of a multiplexed signal in the same manner as described previously for the reference burst signals.

An antenna synchronization 1350-cps oscillator, V608, located in the coder-indicator is used to produce a reference frequency for checking the speed of rotation of the antenna. The frequency output of this oscillator is controlled by a 1350-cps tuning fork, Y601. V608 produces sufficient feedback voltage to sustain the oscillations. The antenna synchronization oscillator circuit is not dependent on the signal output of any other circuit in the coder-indicator.

TRANSMITTER

Actually, the transmitter can be considered to contain a frequency multiplier-oscillator chassis and an amplifier-modulator chassis. It should not be forgotten however, that the local oscillator signal for the beacon receiver is also obtained from the frequency multiplier-oscillator chassis as discussed.

For each pulse fed into the frequency multiplier-oscillator via J1401, two video pulses are developed. On pulse, called the klystron gate pulse, is 10 μs wide and is amplified in succeeding stages of the transmitter to a level sufficient to key the high voltage applied to the klystron V1304.

The second pulse, called the 3.5 μs shaped pulse, is a specially shaped video pulse which is used to intensity-modulate the klystron beam current. This pulse has a relatively long rise and decay time in order that the final r-f output

pulse will occupy a minimum of frequency spectrum.

The output of the coder-indicator, consisting of 3600 pulse-pairs per second, is applied simultaneously to a delay line, DL1401, and to a one-shot multivibrator, V1402. The width of each of the input pulses is approximately 1.5 μs.

The input pulses to the one-shot multivibrator, V1402, trigger this circuit into operation. The output pulses from V1402 are approximately 2.5 μs in duration.

The input pulse to the power amplifier, comprising V1403, V1404, and V1405, is amplified in this stage. The power amplifier tubes are operated in parallel in order to obtain the high-powered pulse required to drive subsequent shaping circuits. A negative rectangular pulse from the power amplifier (approximately 800 volts) is stepped-up across an output transformer (not shown) to a value of about 2300 volts. This pulse is fed to a series diode, V1406, which passes only the positive portions of the pulse, and thereby prevents the passage of negative transients generated in the secondary of the transformer.

The V1406 output is applied to a shaping network. Triangular pulses 3.5 μs wide at the input of the shaping network are reduced in amplitude and shaped into pulses 3.5 μs wide having a gradual rise and decay time. Control of the pulse shape at this point ensures that a minimum of r-f spectrum will be occupied by the final transmitted r-f output pulse.

The 3.5 μs pulse from the shaper network is applied to the grid of a cathode follower, comprising V1407 and V1411 in parallel. These tubes are operated in parallel in order to lower the output impedance of the stage. V1407 and V1411 preserve the shape of the 3.5 μs pulse and apply the output pulse to the klystron power amplifier, V1304.

As stated previously, the 3.5 μs shaped pulse and the 10 μs pulse are applied to the klystron, V1304. The 3.5 μs pulse is delayed approximately 2.8 μs in passing through the shaper network. It is desired that the shaped 3.5 μs pulse will arrive at the klystron, V1304, to coincide with the center portion of the 10 μs gate pulse. Thus, the 10 μs pulse must also be delayed. The required delay is accomplished by controlling the time of the start of the 10 μs pulse by the trigger pulse from the coder-indicator which passes through the delay lines, DL1401 and DL1402, in series.

The output pulse from DL1401 and DL1402 is approximately 2 μs in duration, and is applied to the multivibrator which comprises V1401 and

V1408. The pulse from the multivibrator can be adjusted to produce 10 μs pulses from V1409.

Cathode follower, V1409, produces two outputs. One of the 10 μs outputs from V1409 is applied to the cathodes of the r-f amplifiers, V1505 and V1506. These tubes are normally held cut off by a fixed bias voltage. The negative-going 10 μs gate pulse from V1409 gates V1505 and V1506 into conduction. A constant r-f carrier is applied to the grid of V1505 from the tripler stage, V1504 (discussed later). The r-f carrier is passed through the r-f amplifiers only during the time that the negative-going 10 μs keying pulse is present on the cathodes of the r-f amplifier stage.

The second 10 μs output from V1409, is fed to the receiver blanking gate stage, V401, via J506. This pulse will cause the receiver to be disabled during the transmission of the r-f output pulses to endure that the transmitted energy will not be routed back into the radio beacon.

In addition to developing the required video modulating pulses, the frequency multiplier-oscillator portion of the transmitter provides an r-f carrier signal of sufficient power to drive the SAL 89 klystron in the final power output stage. The r-f carrier is generated by a Butler or Navy-type crystal-oscillator, V1501. The oscillator, V1501, is followed by a group of frequency multiplier stages, comprising a section of V1501 and stages V1502, V1503, and V1504. These stages multiply the basic oscillator frequency 24 times.

The tripler stage, V1504, produces two outputs: one output of V1504 is fed to the mixer stage of the receiver and is used as the local oscillator signal as discussed; the other output of V1504 is constantly applied to the grid of r-f amplifier, V1505. In the presence of the 10 μs pulse from V1409, the keyed r-f amplifiers, V1505 and V1506, are permitted to pass the r-f signal. The output of the keyed r-f amplifiers consists of a 10 μs pulse of r-f energy which drives the klystron, V1304, in the amplifier-modulator chassis.

The amplifier-modulator consists of the klystron r-f power amplifier, V1304, a regulated bias supply, a double-slug tuner, Z1303, and associated control circuits. V1304 is a three-cavity klystron amplifier, having a control grid used to intensity-modulate the klystron beam current, and an r-f input jack, J1309, in the first cavity which is used to velocity-modulate the klystron beam current.

A sectional diagram of the klystron tube is shown in figure 5-11. The klystron operates as a three-cavity amplifier, and depends on the
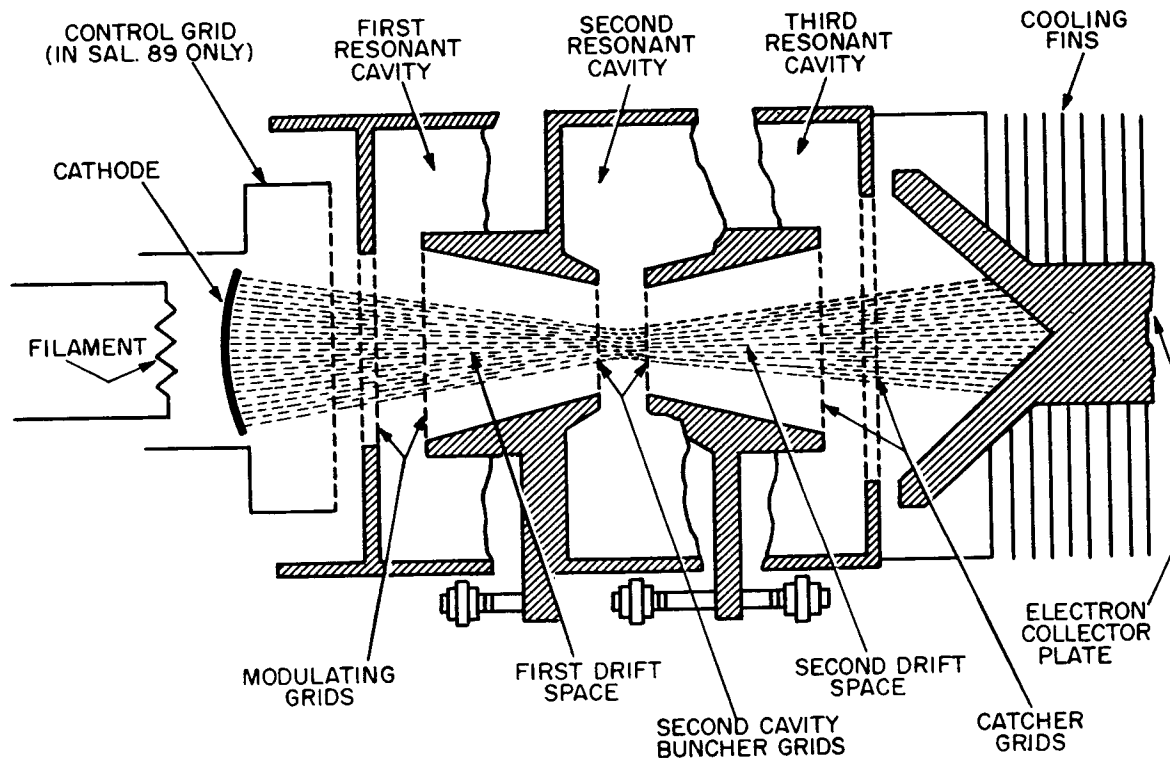
Figure 5-11.—Sectional diagram of klystron tube.

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changes introduced in the velocity of the stream of electrons in the first and second drift spaces (velocity-modulation). The changes in the r-f potential across the klystron resonator cavities alternately slow some of the electrons and accelerate others. This action causes bunching of the electrons during one period, and creates a space between bunches during the next period. The transit time between the two electron groups (or bunches) produces an alternating r-f current through the klystron.

If the area of the klystron cavity is either increased or decreased, the rate of bunching in the klystron will be changed. Cavity tuning is accomplished by mechanically changing the area of the cavity by adjustable screws.

Coincidentially with the application of the 10 μs pulses to the klystron r-f input jack, J1309 (fig. 5-10), the 3.5 μs pulses are applied to the control grid. Klystron beam current, which is normally cut off by negative bias from the regulated bias supply in the amplifier-modulator, is keyed-on by the 10 μs pulse, and grid-modulated by the 3.5 μs shaped pulse. As the beam current passes through the first cavity of the klystron, it is velocity-modulated by the application of the 10 μs r-f pulse to the first cavity of the klystron.

The combined effect of grid-modulation and velocity-modulation of the klystron beam current results in high-powered r-f output pulses from V1304. The shape of the pulse is controlled by the 3.5 μs pulse to ensure that the radiated r-f power will occupy a minimum of frequency spectrum about the assigned carrier frequency as discussed.

R-f output pulses from the klystron, V1304, are fed through coaxial cable, via a double-slug tuner, Z1303, the control-duplexer, and a Switch Test Adapter, SA-420/URN-3, to the beacon antenna. Z1303 is inserted in the transmission path for impedance matching the output of the klystron to the input circuit of the control-duplexer.

CONTROL-DUPLEXER

The control-duplexer consists of a duplexer circuit that permits the transmitter output signal and the receiver input signal to be fed through the same transmission line and antenna. Control circuits located in the control-duplexer

permit the radio set (AN/SRN-6) to be operated by switches on the front panel of the control-duplexer. Also included in the control-duplexer drawer are two resonant cavity filters, Z1156 and Z1157. These filters are inserted in series with the transmission line to limit the overall spectrum of the transmitter output.

The control-duplexer output signals are routed through a Switch Test Adapter, SA-420/URN-3. The switch test adapter consists of a heavy duty coaxial switch, S6151, and pick-off diodes, CR6151 and CR6152. The switch, S6151, transfers the radio beacon transmitter output from the antenna to the dummy load as desired. The pick-off diodes supply detected signals to the test equipment. A biasing voltage is applied to CR6152 to permit power measurement by the slide-back method.

ANTENNA SYSTEM

The shipboard antenna system consists of the antenna proper, the antenna pedestal, a roll and pitch stabilization servo system, a bearing servo system, and a speed control servo system. The basic functions of the antenna were considered earlier in this chapter. The following discussion presents a block diagram analysis of the various antenna systems.

Antenna Speed Control System

As discussed previously, the speed of the rotating cylinders carrying the parasitic reflectors must be maintained constant at 900 rpm, since the speed determines the modulating frequencies. To control this speed, a speed control servo system is employed. A tachometer that is an integral part of the motor which rotates the antenna (spin motor) generates a 675-cps signal when the antenna cylinders are spinning at the required 900 rpm.

The speed control circuit (fig. 5-12) consists of a preamplifier and a power amplifier. The preamplifier comprises a phase-sensitive detector, an equalizing network, a voltage amplifier, and an oven control amplifier with its associated circuits. The power amplifier consists of three saturable reactors with their associated feedback rectifiers and power factor correction transformers.

The spin motor, B3203, which is geared to the tachometer, G3202, causes the tachometer to generate the 675-cps signal when the antenna is being rotated at the proper speed (900 rpm). Any deviation from this speed causes a corresponding change in the frequency of the signal from the tachometer. This frequency is fed to the input of the antenna speed control preamplifier circuit.

The phase-sensitive detector in the preamplifier contains a tuned circuit which is resonant at 675 cps. If the tachometer frequency is the same as the resonant frequency of the phase detector, no error voltage will be developed. However, if the tachometer frequency varies from the required 675 cps, the phase detector
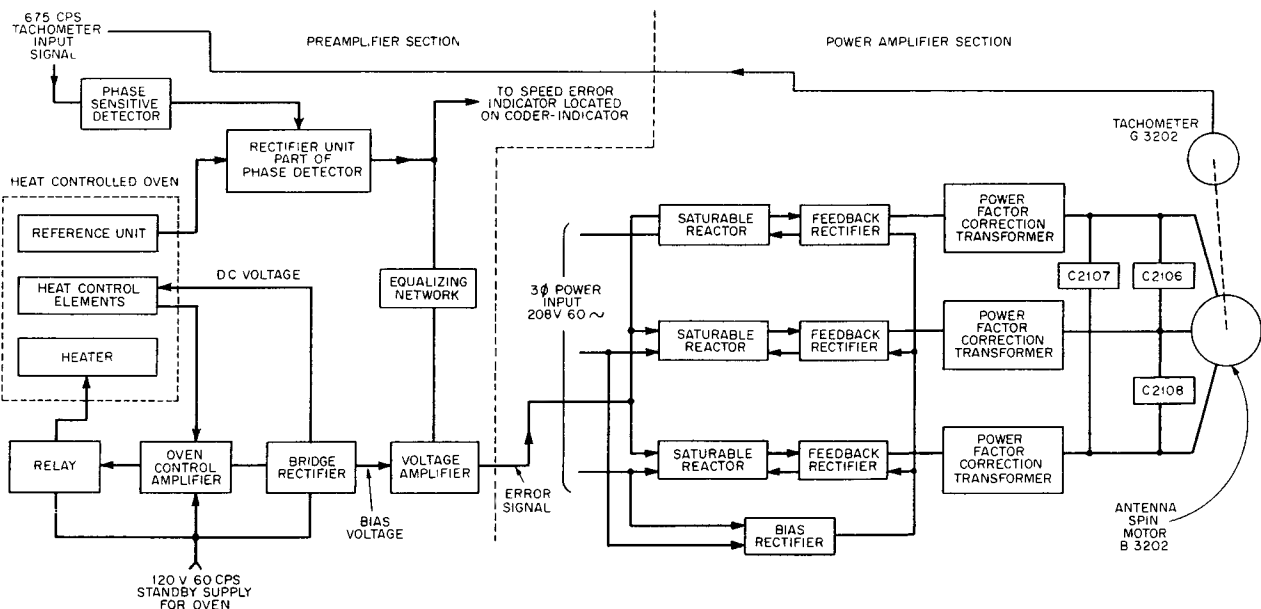

Figure 5-12.—Antenna speed control circuit, block diagram.

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will produce an output voltage which is proportional to the magnitude of the frequency error.

The error voltage is produced in the rectifier unit which is a part of the phase detector. The output of the rectifier unit is fed to the speed error indicator located on the front panel of the coder-indicator, and through an equalizing network to the voltage amplifier.

The heat-controlled oven contributes to the frequency stability of the tuned circuit in the phase-sensitive detector. A separate amplifier used for controlling the oven temperature senses any change in the temperature and operates a relay that controls the current to the heating elements in the oven. Direct current for the heat control elements is supplied by a bridge rectifier, which also supplies d-c bias for the voltage amplifier.

The voltage (magnetic) amplifier receives the speed error voltage developed in the phase-sensitive detector circuit, amplifies it, and converts the error voltage to its equivalent d-c voltage. The equalizing network stabilizes the operation of the amplifier by removing ripples from the error signal, thereby preventing the amplifier from saturating because of noise voltages.

The output of the voltage amplifier is applied to the control winding of three saturable reactors. The load winding of each of the reactors is in series with one phase of the 3-phase power line, which supplies power to the spin motor. Thus, the line current supplied to the speed control motor is directly controlled by the effective impedance of the series reactors.

For low values of d-c control current to the spin motor, the saturation is low and the impedance is high. The motor voltage is decreased and the motor will slow down. Conversely, for large values of control current the motor voltage will be increased, due to the lowered reactor impedance, and the motor will speed up.

A bias rectifier is placed across one phase of the input power to supply the three separate bias windings of the saturable reactor. Each bias winding is shunted by a single dry-disk rectifier (not shown). The rectifier damps oscillatory currents and suppresses harmonics of the line frequency that are introduced in the windings of the reactor.

In the AN/SRN-6, the power factor correction capacitors C2106, C2107, and C2108 are not used. The output from each of the saturable reactors is fed through its associated autotransformer to separate control phases of the 3-phase motor. The transformers step up the line voltage for each phase of the input power

to compensate for losses introduced by the power windings of the saturable reactors.

Bearing Servo System

The bearing servo system (fig. 5-13) is used to maintain the radio beacon's 15-cps reference pulse coil subassembly fixed with respect to corrected magnetic north.

The angular position signals for true north are continuously transmitted from the ship's gyro compass through the ship's bus to the radio beacon. The magnetic variation subassembly, located in the coder-indicator, is manually adjusted to correct the ship's gyro compass information for magnetic north.

The magnetic correction signals are manually set into the 1- and 36-speed differential transmitters of the magnetic variation subassembly, CDX-601 and CDX-602, respectively. The sum of the gyro compass and magnetic variation signals is forwarded to the azimuth 1- and 36-speed control transformers in the antenna base.

As long as the rotors of the control transformers are at the same effective angular position as that of the differential transmitters, after summing the signals of the ship's gyro compass and the magnetic variation signals, no control transformer output is sent to the bearing amplifier. If the equilibrium is upset due to displacement of the rotors of the differential transmitters to new positions by changing the setting of the magnetic variation unit, or should the course of the ship change, an error voltage will be induced and transmitted from the control transformer to the bearing servo amplifier.

The bearing servo amplifier, having received its signal, sends power to the servo motor, and causes it to rotate in the proper direction to restore the rotors of the control transformers to the zero signal position. At the same time the control transformers are being restored to equilibrium, the gear train rotates the pick-off coil of the pulser plate assembly enabling the 15-cps reference of the transmitted signal to be oriented to magnetic north as dictated by the ship's course and the magnetic variation subassembly.

The bearing servo motor is a 2-phase induction motor having a continuously excited phase and a variable phase. The output torque of the motor is roughly proportional to the current delivered by the bearing amplifier. The direction of the torque is determined by the polarity of the control voltages.

The magnetic variation subassembly contains two dials which enable the operator to manually

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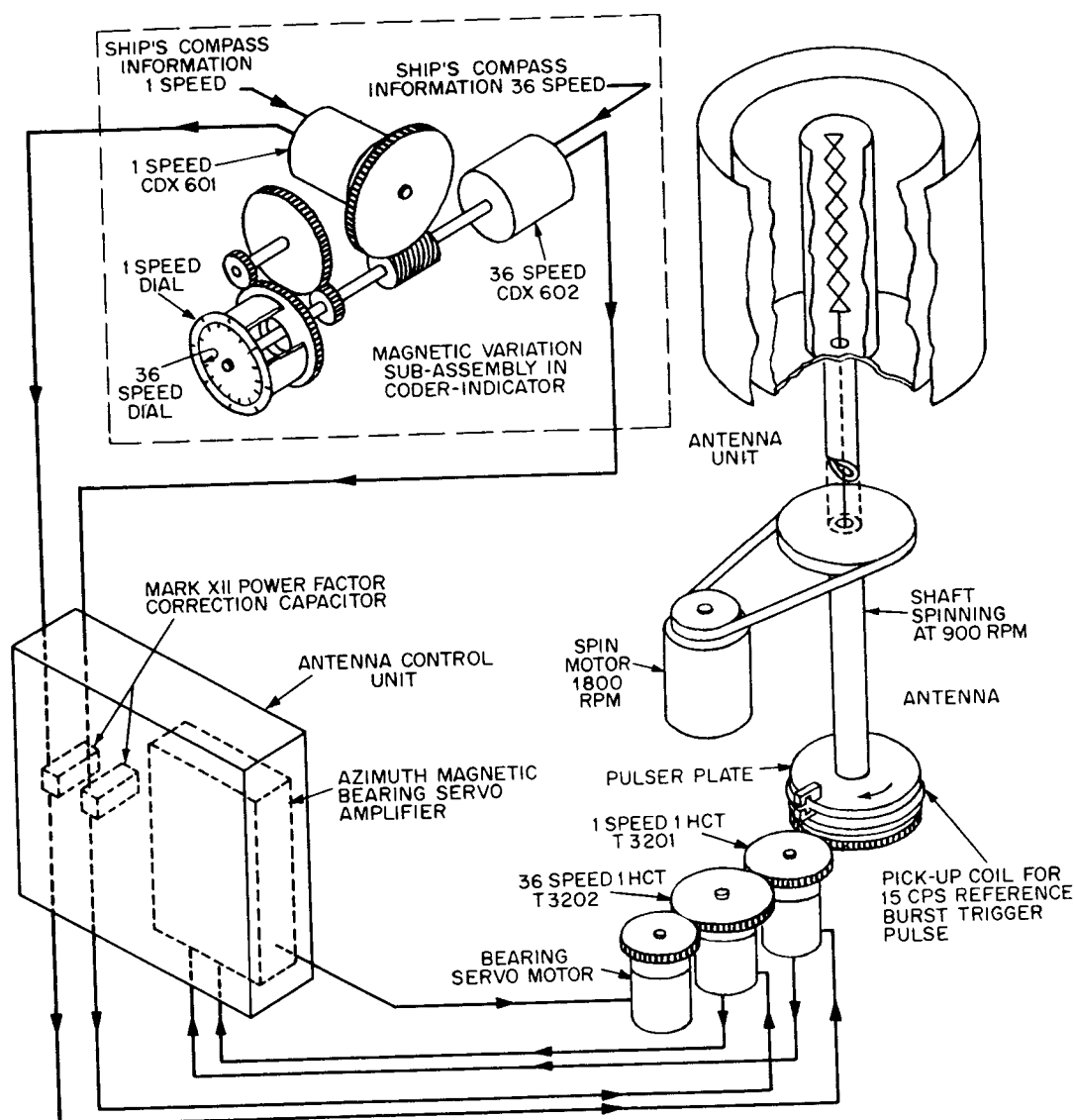
Figure 5-13.—Shipboard bearing servo system.

set into the system the corrected magnetic variation signals. One of the dials is calibrated in 360° of bearing and is attached to the rotor of the 1-speed differential transmitter, CDX-601. The second dial is calibrated from 0° to 10° and is connected to the 36-speed synchro. Both dials are displayed concentrically on the front panel of the coder-indicator.

The use of the 2-speed synchro transmission system provides greater accuracy in determining shaft angles. For example, while the dial connected to the 1-speed synchro can be adjusted quite closely to the actual angular position of the shaft, the use of a 36-speed gear ratio with a corresponding dial calibrated from 0° to 10° increases the ready accuracy. The 36-speed control makes one complete revolution for every 1/36 revolution of the coarse adjustment (1-speed) dial. Since one revolution of the fine control dial represents 10° on the coarse adjustment, the shaft positions can be read with 36 times the accuracy.

Roll and Pitch Servo Systems

The roll and pitch servo systems (fig. 5-14) are separate but similar circuits which maintain the antenna in the vertical position with
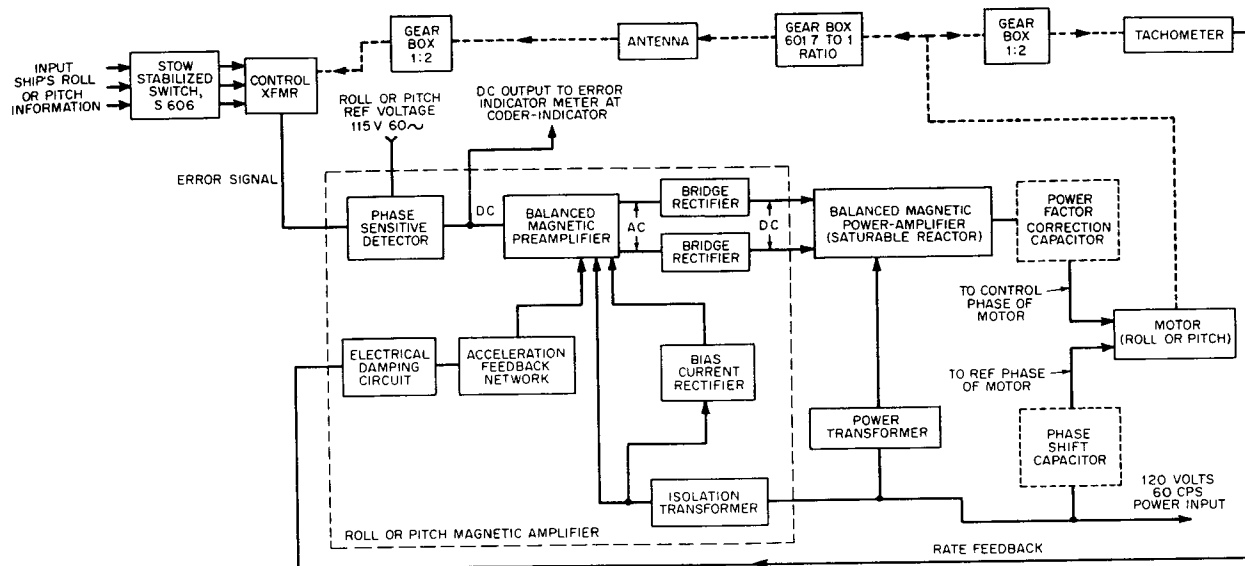
Figure 5-14.—Roll and pitch servo system, block diagram.

respect to a horizontal plane despite roll and pitch motions of the ship on which the antenna is mounted. The roll servo system can correct up to 25° of roll, while the pitch servo system can correct up to 6° of pitch. Roll and pitch information is obtained from the stable element of the ship which is gyroscopically controlled to maintain a true horizontal position.

A 2-position (stow-stabilized) switch, S606, is located on the front panel of the coder-indicator. In the STOW position, the antenna is erected perpendicular to the deck of the ship, and the roll and pitch servo systems are not in control of the antenna. When S606 is in the STABILIZED position, (which is its normal position aboard ship) the antenna will be held in a fixed position by the servo systems so long as the roll or pitch of the ship does not exceed the specified limits as described above.

The roll servo system and the pitch servo system are almost identical. The following discussion applies to both systems unless otherwise noted.

Roll and pitch information is fed from the bus of the ship through the stow-stabilized switch, S606, in the STABILIZED position, to the control transformer. The control transformer passes the error signals to the roll or pitch magnetic amplifier. The error signal is phase detected, amplified, and converted to a d-c voltage to operate a balanced magnetic power amplifier (saturable reactor). The output of the magnetic power amplifier is fed

through a power factor correction capacitor to the control phase of the roll or pitch motor.

The servo motor, through its associated gear train, moves the antenna to its corrected position. At the same time, the gear train nulls the error signal at the control transformer through a 1:2 gear box. The gear train also turns a tachometer which produces a rate feedback voltage. This signal is converted into acceleration feedback and applied to the balanced magnetic preamplifier. The feedback is degenerative to the action of the amplifier and therefore tends to prevent oscillations in the roll or pitch servo systems. The method used to convert the rate feedback to acceleration feedback is discussed in chapter 6 of this training course.

Blowers (not shown) are connected to the pitch and roll motors to help dissipate the heat generated in the unit. Brake solenoids, a part of the apparatus, lock the position of the antenna in roll or pitch when the equipment is deenergized.

The bubble canopy (fig. 5-1), which protects the antenna and pedestal from the weather, also decreases wind resistance. Without the bubble canopy, larger servo motors would be required.

CIRCUIT ANALYSIS OF RADIO RECEIVER

The radio receiver (fig. 5-15) performs the following functions:
1. Receives from the control-duplexer the interrogation pulse-pairs transmitted by the aircraft.
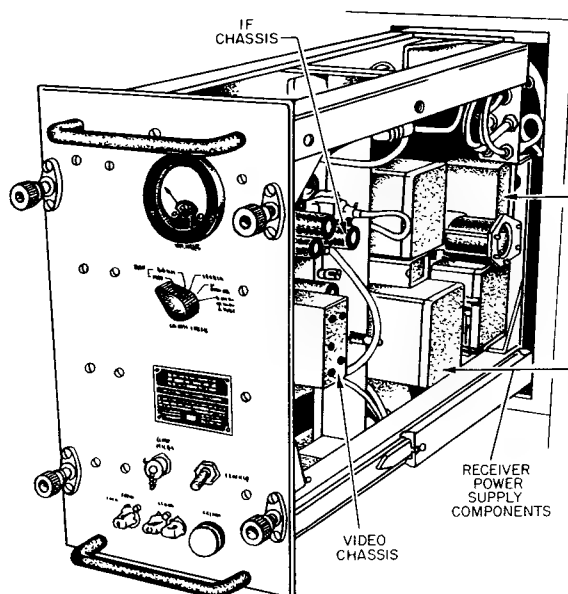
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Figure 5-15.—Radio receiver, overall view.

2. Converts the received distance interrogation pulse-pairs, along with random noise pulses generated within the receiver mixer and first preamplifier stages, into an intermediate frequency of 63 mc, and amplifies and demodulates these signals.

3. Produces, by means of a coincidence-type decoding circuit, a single pulse for each interrogation or noise pulse-pair. The pulses must be separated by 12 μs and of sufficient amplitude to trigger the coincidence-decoder circuit.

4. Assures, by means of a blanking circuit, a separation of at least 40 μs between decoded pulses. The blanking circuit does not permit passage of any pulse through the receiver which occurs less than 40 μs after the preceding pulse.

5. Maintains the total pulse output constant at 2700 ±90 pulses per second, regardless of the interrogation rate.

The radio receiver contains four subassemblies. These are: a mixer-preamplifier, an i-f amplifier, video amplifier, and a power supply. The circuit operation of each of these subassemblies follows.

MIXER

The distance interrogation pulses from the antenna are fed through a duplexer (discussed later) to a low-pass filter, Z501, in the receiver (fig. 5-16). Z501 rejects frequencies

between 1,650 and 10,000 mc, and passes the interrogation pulses to the hybrid balanced mixer circuit. The mixer input signal is first applied to two crystal diodes, CR201 and CR202. A local oscillator signal is fed to the junction of CR201 and CR202 from the carrier generating chain in the frequency multiplier-oscillator.

The interrogation pulse-pair carrier frequency will be between 1025 and 1087 mc on the low band, and 1088 and 1150 mc for high-band operation. The local oscillator signal must be of the proper frequency to produce a 63-mc output from the mixer.
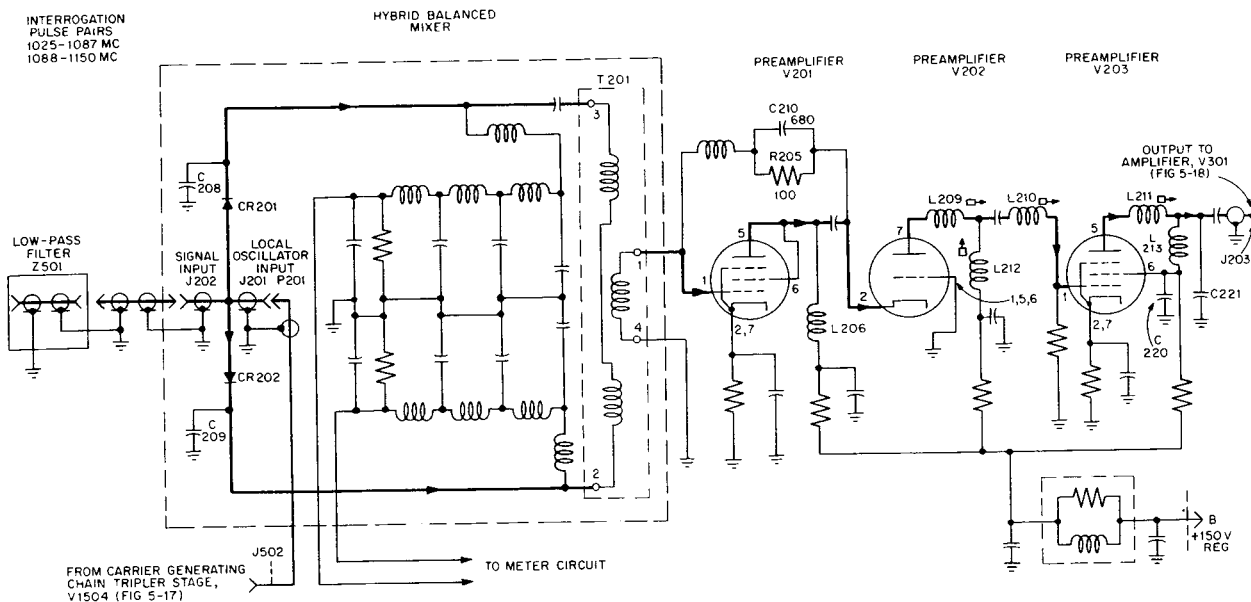
CARRIER GENERATING CHAIN

The carrier generating chain (fig. 5-17), which produces the local oscillator frequency for the receiver, comprises an oscillator-frequency doubler, V1501, which is followed by a second doubler, V1502, a third doubler, V1503, and a tripler stage, V1504.

The oscillator circuit, V1501, is a Butler- or Navy-type crystal oscillator and frequency doubler, having an oscillator frequency output of between 40.083333 mc to 42.666667 mc for the low-band, and from 47.958333 mc to 50.541667 mc for the high-band frequencies. The high- and low-band circuits are identical except for several tuning components which have slightly different values to compensate for the difference in the frequency range to which they must tune.

The following discussion refers only to the high-band circuit components. The frequency output of the following circuits is for channel 113, which is a representative high-band channel. The frequency output from the oscillator portion of V1501 (which is V1501A) for operation on this channel is 50.000000 mc, and for the doubler portion (V1501B) is 100.000000 mc.

The oscillator frequency is controlled by a crystal, Y1501. An oscillator is basically an amplifier with a positive feedback path. V1501 is a double triode which is connected as two separate amplifiers with positive feedback supplied from the B section of V1501 to the A section. V1501A is a grounded-grid amplifier. Its input is the crystal frequency which is developed across R1502. The plate circuit of V1501A is tuned to the oscillator frequency (50 mc) by adjustment of L1502. The oscillator, V1501A, frequency is coupled through C1504 to the control grid (pin 3) of V1501B.

V1501B is a harmonic generator-phase inverter. The cathode output of V1501B which is developed across R1503 provides regenerative

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Figure 5-16.—Receiver mixer and preamplifier.
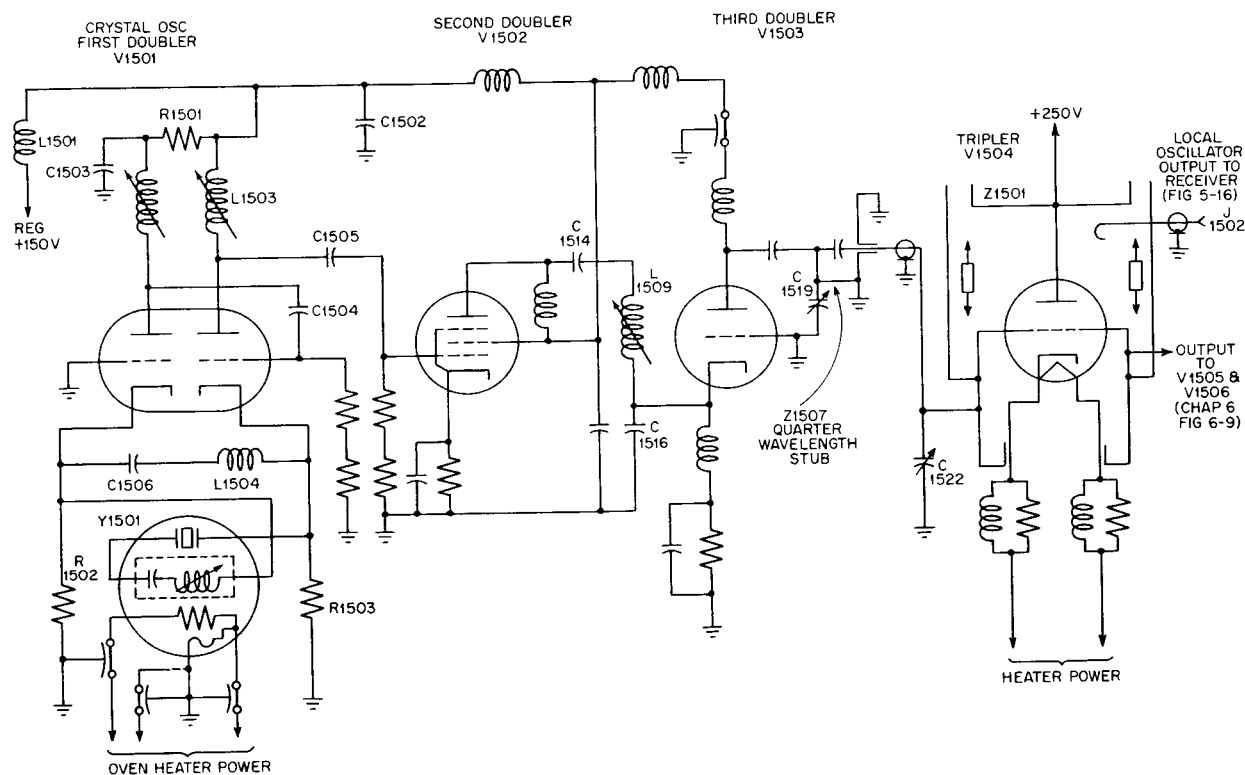
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Figure 5-17.—Carrier generating chain.

feedback to the grounded grid amplifier, V1501A, as necessary to sustain oscillations. The frequency at which the feedback takes place is established by the crystal, Y1501. The feedback path through the crystal is a low impedance path at the oscillator frequency only.

The plate of V1501B is tuned to the second harmonic of the oscillator frequency (100 mc). Tuning is accomplished by adjustment of L1503. The output is coupled through C1505 to the second doubler stage, V1502.

L1501, C1501, and C1502 form a filter network to prevent the introduction of the oscillator r-f signals from the oscillator plate to the plate power source. R1501 and C1503 also act as a filter (decoupling) for the oscillator output. The combination of C1506 and L1504 ensures that the oscillator frequency stability is maintained by cancelling the capacitive component of the crystal circuit impedance.

A frequency of 100 mc (which is the output frequency of the oscillator-first doubler stage, V1501) is fed to the control grid (pin 1) of the second doubler stage, V1502. The plate circuit of V1502 is tuned to the second harmonic of the input frequency. Tuning is accomplished by adjusting L1509. The output frequency of the second doubler stage, V1502, is 200 mc and is fed to the third doubler stage, V1503. L1509 and C1516 form a series resonant circuit which is tuned to the 200 mc second harmonic of the input frequency to V1502. The 200 mc output is coupled to the series resonant circuit by C1514.

The third doubler stage, V1503, is connected as a grounded-grid amplifier. The grounded-grid amplifier is very useful at high frequencies since it effectively removes the grid-plate feedback coupling which might cause undesired oscillations in a conventional grid-input-grounded cathode amplifier. The grid-plate interelectrode capacitance is placed in parallel with the load.

The output of V1503 is coupled through Z1507 to the cathode of the tripler stage, V1504. The series tuned resonant circuit, comprising C1519, Z1507, and C1522, is tuned to the second harmonic of the V1503 input, or 400 mc.

The tripler stage, V1504, employs a 2C39A lighthouse tube in conjunction with a broad-band coaxial type of resonant cavity, Z1501. The third doubler output, which is fed to the cathode of V1504, is amplified, and appears with a large third harmonic content in the plate circuit. A coaxial line type cavity, Z1501, is connected between the plate and grid of this circuit. The cavity is tuned by means of tuning screws. As the screws are turned, the capacity applied

across the cavity is varied, and thus changes the resonant frequency of the grid-plate circuit.

Physically, the grid-plate cavity of the tripler stage, V1504, consists of a concentric line. The shell, and the anode cap which is capacity coupled to it, for the outer conductor. The grid line forms the inner conductor.

The tripler signal at 1200 mc is picked up by loops connected to the grid line. The tripler stage, V1504, has two outputs. One of these outputs is applied to the first keyed r-f amplifier, V1505, and will be discussed in chapter 6 of this training course. The second output at J1502 is fed to the mixer stage of the receiver (fig. 5-16) to be used as the receiver local oscillator signal.

It should be remembered that the frequency of the tripler, V1504, output (fig. 5-17) to the mixer stage is determined by the crystal, Y1501, in the crystal oscillator, V1501. The range of crystal frequencies was stated earlier.

For the particular channel selected (channel 113) the local oscillator frequency would be 1200 mc. The carrier frequency of the interrogation pulse-pairs for this channel is 1137 mc. Thus, the required difference frequency of 63 mc is produced in the mixer circuit (fig. 5-16).

Essentially, all power into the signal input and local oscillator arms of the mixer circuit is delivered to the two crystal mixers, CR201 and CR202. As a result, a rectified difference frequency is produced across the mixer output transformer, T201. Because of the phase relationship of the carrier and interrogation pulse-pair signals across the output transformer, cancellation of these signals occur at the transformer.

T201 is tuned by C208 and C209 to resonance at 63 mc. The sum and original frequencies are shunted by these capacitors, allowing only the difference frequency to be developed across the output tank. The output of the mixer circuit is coupled by the T201 secondary to the grid of the preamplifier stage, V201.

PREAMPLIFIER STAGES

Preamplifier stage, V201, amplifies the 63-mc signal coupled from the T201 secondary. V201 is a sharp cutoff pentode, which is connected as a triode. The stage functions as a conventional triode amplifier.

The plate load inductor, L206, is slug-tuned to facilitate alignment of the amplifier for a relatively flat i-f response centered at 63.0 mc. The V201 output is coupled to the cathode of a grounded-grid amplifier, V202. The overall

circuit arrangement of V201 and V202 is that of cascode r-f amplifiers, which provide about the same gain as a single-stage pentode amplifier but with considerably less noise.

Bias voltage for V202 is developed across R205 and C210. Degenerative feedback is also established since the signal output is developed back at the V201 grid through the V202 cathode conduction via the T201 secondary.

Coupling between V202 and V203 is accomplished by a TEE arrangement of series and parallel tuned circuits. L209 and L210, with their associated distributed capacitances, form the series peaking circuit. These inductors contain adjustable slugs, which vary the point of resonance (peaking) of the circuit. L212 is a shunt peaking circuit for the output. A similar coupling arrangement is employed in the V203 output circuit, using L211 as the series peaking coil and L213 as the shunt coil.

V203 is a conventional pentode amplifying stage which amplifies the 63.0-mc signal. L206, L209, L210, and L211, produce a relatively flat i-f response centered at 63.0 megacycles.

The plate circuit of V203 is the parallel resonant circuit which consists of the tube output capacitance, L211, L213, C221, and C220. The output voltage is obtained across L213, C220, and C221, at a low impedance level which matches the impedance of the 50-ohm coaxial cable that feeds the i-f signal to the i-f amplifier stages (fig. 5-18).

INTERMEDIATE FREQUENCY AMPLIFIERS

The receiver i-f amplifiers (fig. 5-18) increase the amplitude of the signal and of the noise received from the preamplifiers to a level sufficient to operate the Ferris discriminator. A variable negative bias (squitter-control voltage), dependent on the number of interrogation and noise pulses out of the receiver, is applied to two of the i-f amplifiers. This negative voltage (discussed later) controls the gain of these stages and thereby controls the number of pulses out of the receiver.

Echo suppression circuits are employed in the i-f amplifiers which allow operation of the equipment in the vicinity of large reflecting objects.

The signal output of the preamplifier stage, V203, is applied to the control grid of the first i-f amplifier, V301. The input circuit to the control grid of V301 consists of C304, L301, C302, L302, and the input capacitance of V301. L302 and the tube capacitance form a series resonant circuit which provides a step-up in

voltage and impedance from the 50-ohm coaxial line to the grid input. Because of the impedance matching afforded by the circuits at the input and output of the coaxial line, the i-f response is substantially independent of the cable length between the preamplifiers and the i-f amplifier, V301.

The i-f voltage is amplified in five stages of i-f amplification, comprising V301 through V305. The plate tuning inductors of V301 through V304 are stagger-tuned to center the i-f response around 63 mc, and to provide an i-f bandwidth of 2.0 megacycles.

FERRIS DISCRIMINATOR

The Ferris discriminator circuit, V306, receives its input signal from the final (fifth) i-f amplifier, V305. The function of the Ferris discriminator is to detect the signal and provide adjacent and near-adjacent channel rejection.

The input signal to the Ferris discriminator is coupled to two tank circuits. These circuits comprise L308, C334, C335, and L309, C337, C338. Low impedance points on the tank circuits are used to feed the discriminator diodes, V306A and V306B, respectively. In this way, the tube capacitance is shunted across a smaller portion of the total tank impedance. Thus, the discriminator is relatively unaffected by variations in tube capacitance. In addition, the circuits are temperature compensated to maintain frequency stability over the temperature range from -54° C to $+85^\circ$ C (-65° F to $+183^\circ$ F).

Both of the tank circuits feeding V306 are tuned to 63 mc. Because of the loading difference imposed on the tank circuit which feeds V306B (by R343), the "Q" of the tank circuit feeding V306B is reduced to approximately one-third the "Q" of the tank circuit feeding V306A. Each half of V306 has a different frequency characteristic because of the differences in the signal developed by each tank circuit.

V306A attempts to conduct a negative output across R326 and C340, while V306B attempts to develop a positive output across R325 and C339.

Since the "Q" of the V306A tank is higher than that of the V306B tank, the negative voltage developed by the V306A conduction at the center of the i-f band is greater than the positive voltage developed through the V306B conduction at the same frequency. V306A and its associated tank, therefore, passes only a negative-going narrow band of frequencies centered at 63 mc. The characteristics of the V306A tank circuit are shown in A of figure 5-19. V306B and its

A

V306A OUTPUT CHARACTERISTIC

B

V306B OUTPUT CHARACTERISTIC

ADJACENT CHANNEL
FREQUENCIES

C

V306A AND V306B COMBINED
OUTPUT CHARACTERISTIC AT
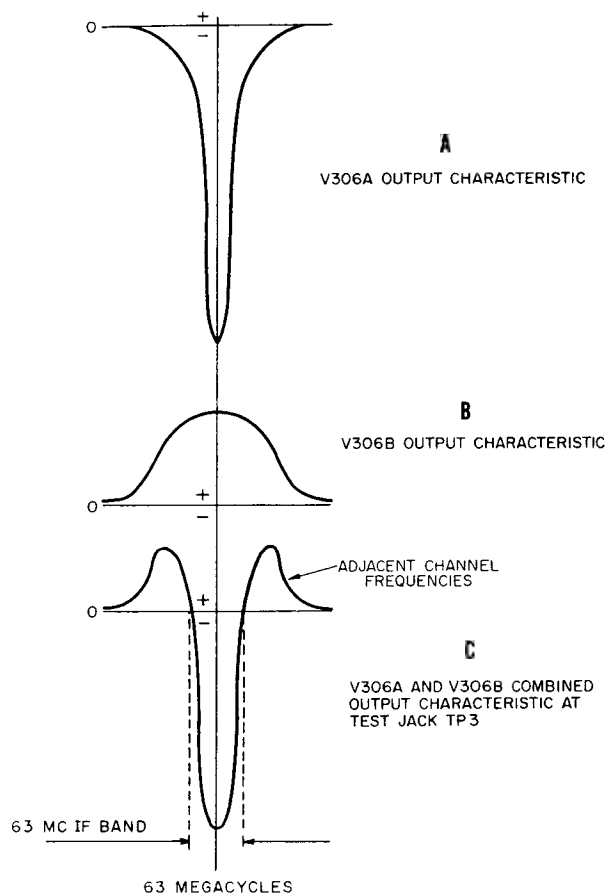TEST JACK TP3

63 MC IF BAND

63 MEGACYCLES

32.90

Figure 5-19.—Ferris discriminator, c-w
frequency response characteristics.

associated tank will pass a positive-going wider
band of frequencies also centered at 63 mc.
The curve representing the response charac-
teristics for the V306B output is shown in B of
figure 5-19.

The algebraic sum of the V306 output volt-
ages as it is applied to the first triode video
amplifier, V307A, is as represented in figure
5-19C. The normal V306 output to V307A is
negative interrogation signals, within the 63-mc
i-f pass band, that are amplified normally in
V307A.

Note that a positive voltage appears on the
V307A grid for adjacent channel frequencies.
V307A is lightly biased as a result of low
V307A conduction through R342. The output of
V306 is also applied to the plate of a clamping
diode, V308A. When adjacent channel (positive)
frequencies appear at the V307A input, clamp-
ing diode, V308A, conducts to quickly C362
negative toward the grid side through C340 and
C339. This negative voltage is sufficiently

large to cut off V307A for the duration of the
adjacent channel input.

The inverted output at the plate of V307A is
applied through C343 to the grid of a similar
circuit comprising V307B. Positive input sig-
nals are amplified in V307B. Negative input
signals developed across a clamping diode,
V308B, to cut off V307B, thereby eliminating
any remaining portion of the adjacent channel
frequencies.

The output of the Ferris discriminator and
video amplifier consists of interrogation pulse-
pairs spaced 12 μs apart.

VIDEO AMPLIFIER STAGES

The video stages decode the interrogation
pulse-pairs and a sufficient number of noise
pulses to maintain the receiver output at 2700
±90 pulses per second. In addition, the video
amplifier blanks itself out for 40 μs after each
decoding of a pulse-pair, so that a 40 μs time
minimum is maintained between pulses delivered
from the output of the receiver to the input of the
coder-indicator.

The video signal (interrogation pulses) and
noise pulses from V307B are routed through
C345 and J402 to the control grid of the first
video amplifier, V402A. A portion of the input
signal is fed through C409 to the control grid of
cathode follower, V405, for purposes described
later. The output of V307, which represents the
output from the i-f amplifier chassis, can be
checked at test point 5 (J409).

The video signal is amplified in V402A and
passed through C401 to the control grid of the
blanking gate stage, V401. The gating action of
this stage and the amplitude and shape of the
gate pulse will be considered later. It is suf-
ficient at this time to state that V401 passes the
video signal and the noise pulses.

The output of the blanking gate stage, V401,
is coupled by C402 to the control grid of the final
video amplifier, V402B. Positive portions of the
input are clipped by the action of CR403. The
plate output is applied via C403 directly to the
suppressor grid of the decoder tube, V403, while
the control grid signal is fed through a 12 μs
delay line. It should be recalled that the inter-
rogation pulse-pairs are spaced 12 μs apart.

V403 is a semi-remote cutoff pentode biased
to cutoff by a positive voltage obtained from the
junction of R411 and R414, which form a voltage
divider from the B supply to ground. Conduc-
tion of V403 requires the simultaneous applica-
tion of positive voltage on both the control grid
suppressor grid.

When the first pulse of an interrogation pulse-pair, or the first positive pulse of a pair of noise pulses (separated by 12 μs) arrives at the suppressor grid of V403, it is not applied simultaneously to the control grid because of the 12 μs delay line, DL401. Thus, V403 remains in the cutoff condition.

After 12 μs have passed, the first pulse of the pair arrives at the control grid coincidentally with the arrival of the second pulse at the suppressor grid. V403 therefore conducts when the second pulse of a pulse-pair is on the suppressor grid, and the first pulse is on the control grid.

The characteristics of the decoder (V403) ensure that only those pulses (noise or interrogation) having a spacing of 12 μs will be acted upon by the decoder circuit. It should be noted, however, that since the decoder is biased to cutoff, the pulse input must be of sufficient strength to cause conduction. This means that not all decodable noise or interrogation pulse-pairs will be decoded, but only those above a minimum value. The receiver is designed to maintain the number of decoded pulse-pairs at 2700 ± 90 pulses per second.

The decoder (V403) output consists of a single negative-going pulse for each decoded pulse-pair. This pulse is used to trigger a one-shot multivibrator, V404.

V404A is zero biased and normally conducts. V404B is held beyond cutoff by a positive voltage developed at its cathode by R418, which is a portion of a voltage divider comprising R418 and R420, connected from the B supply to ground. The negative input from V403 cuts off V404A to cause its plate voltage to rise, initiating the multivibrator action.

V404 provides three output signals. One output (from the V404B plate) feeds the radio receiver blanking one-shot multivibrator, V406. A second output is coupled to a pulse amplifier, V408, in the radio receiver squitter-control circuit (discussed later). The third output feeds one of two cathode follower output stages in V405.

The output of V405B is a video pulse with an amplitude of about +30 volts and a duration of between 3 and 4 μs. This signal is the output of the radio receiver, which is applied to the video output jack, J504, for connection by inter-unit cabling to the keyer circuits of the coder-indicator. The output is also made available at test output jack, J407, for test purposes.

The second cathode follower, V405A, serves as an output stage to provide a portion of the video signal derived from the Ferris discriminator as it appears before decoding at the input to the video circuit. The undecoded interrogation pulse-pairs and noise appearing at the output of this cathode follower stage are made available at the "future use output" jack, J503, for application to special external equipments.

BLANKING GATE CIRCUITS

The blanking circuit performs a dual purpose. It is responsible for the blocking of the decoder input circuit for 40 μs after a pulse-pair has entered the circuit, and for eliminating undesirable feedback from the klystron in the transmitter to the receiving circuits during transmission.

The B section of the blanking multivibrator, V406, is normally held beyond cutoff as a result of the positive voltage at the R436-R441 junction, which is applied to the V406 cathode. V406A normally conducts, since cathode bias alone controls the current through this tube section.

The negative-going output of the V404B multivibrator plate cuts off V406A. The plate voltage rise of this tube section is coupled by C418 to the B section of V406, causing conduction. The positive output at the V406B cathode is coupled by C420 to the blanking phase inverter and isolation amplifier, V407B. Note that V407B receives a high value of bias from the -105-volt regulated supply. Thus, conduction takes place only on strong positive pulse signals from the multivibrator.

The V407B input pulse is amplified and inverted, and fed to the suppressor grid of blanking gate stage, V401.

It should be recalled that the second pulse of the input pulse-pair caused the triggering action at the V404 multivibrator. Likewise, the trigger to the blanking multivibrator, V406A, corresponds in time with the second pulse of the input pair. The blanking pulse to V401 ensures the cutoff of this stage for 40 μs from the leading edge of the second pulse of the pair.

Blanking time is adjustable by means of "blanking time adjust" potentiometer, R443, which varies the time constant of the RC network to the multivibrator. The control has an adjustment range of between 20 and 65 μs, but is preset at the factory to produce a blanking time of 40 μs.

An additional blanking time in V401 is caused by a positive 10 μs pulse received from the frequency multiplier-oscillator. This pulse ensures blanking of the receiver during transmission of a pulse from the beacon transmitter.

Since each pulse is approximately 3 μs wide, and the blanking gate stage, V401, input corresponds in time to the second pulse of the pair, the elimination of the first pulse in the pair (by the decoder circuit) adds 3 μs to the total time between the arrival of the leading edge of the first pulse to V401 and the leading edge of the next pulse. Thus, the total time between pulses at the output of the receiver as stated earlier in this chapter, is equal to the sum of the 40 μs delay in V401, the 10 μs delay caused by the pulse from the frequency multiplier-oscillator, the original 12 μs between pulses of a pair, and the 3 μs created by the omission of the first pulse of the pulse-pair or 65 μs.

SQUITTER CONTROL CIRCUIT

The output of the V404B multivibrator cathode, which is applied via C416 to the control grid of the pulse amplifier, V408, is used to derive the squitter-control voltage. Squitter control involves the action of a circuit in its use of noise pulses to maintain the total pulse-pairs in the receiver at 2700 ±90 pulses per second.

Grid limiting is permitted at the input to V408, which renders the output of this stage substantially independent of the amplitude of the input pulse. The output of V408 is transformer coupled by T401 to the pulse stretcher and counter diode, V409B. As V409B conducts only on negative input alternations, C415 charges negative toward the plate of the diode. C415 holds most of its charge during positive alternations at the V409B cathode, since the only discharge path is through the high resistance of R433. As a result of this action, the voltage on the grid of V407A is essentially a d-c voltage. V407A is connected across both the negative and positive voltage supplies. The cathode connects through R426 to the -150-volt source, while the plate connects directly to the +150-volt regulated source.

The potential at the cathode of V407A is applied to the first and second i-f amplifiers (V301 and V302) as squitter (gain) control voltage. When the bias voltage on the grid of V407A is correct to effect a squitter rate of 2700 ± 90 pps, the voltage on the cathode of V407A (because of the drop across R426) is approximately -5 volts with respect to ground. This -5 volts at the grid of the first and second i-f amplifiers controls the gain of these stages.

If the receiver output tends to fall below 2700 ±90 pps, the number of pulses fed into the pulse amplifier, V408, also decreases. This results in a lower d-c output from the pulse stretcher, V409B, and a less negative bias on the grid of V407A. Increased current flow in this stage results in a greater voltage drop across R426, and consequently a less negative voltage at the cathode with respect to ground. The reduced negative squitter-control voltage to the i-f amplifiers results in a general increase in the level of the signal reaching the decoder. Thus, a greater number of decodable pulses attain sufficient amplitude to operate the decoder.

If the pulse output tends to rise above the requisite number (2700 pps), a greater number of pulses reach the pulse amplifier, V408, and are coupled by T401 to the pulse stretcher and counter circuit. The increased number of pulses to V409B charges C415 to a higher value, and the bias between the control grid and cathode of V407A is increased. The decreased current through R426 increases the negative potential applied to the i-f amplifier grids, and the rise in the number of decodable pulses reaching the decoder is prevented.

Since without the application of the bias voltage to the grid of V407A (as is the case when the equipment is initially turned on) the voltage drop across R426 may result in a high positive voltage (in excess of +20 volts d-c) applied to the i-f amplifiers, a d-c clamp diode, V409A, operates to prevent the voltage rising above +5 volts while the receiver is warming up. Without the clamping action of V409A, the +20 volts applied to the grids of the amplifiers will completely block the receiver, and may cause damage to the receiver tubes.

As soon as the receiving tubes become heated to their operating temperature, pulses are decoded, and bias is applied to the V407A grid. The voltage drop across R426 (the squitter-control voltage) becomes negative with respect to ground, and V409A ceases to conduct.

POWER SUPPLIES

The radio receiver power supplies (fig. 5-18) provide regulated -150 volts d-c for the video amplifier circuits, and regulated +150 volts d-c for the complete receiver. The supplies are electronically regulated by V503, V504, V505, and V506.

METERING CIRCUIT

A meter, M501, and a 6-position meter selector switch, S501, are used to permit the operator to observe the operating condition of the

mixer crystal diodes (CR201 and CR202 of figure 5-16), the B (+200 volt) and C (-200 volt) power supplies (fig. 5-18), and the squitter control output. The +200- and -200-volt supplies provide regulated +150 and -150 volt outputs respectively.

Figure 5-10.—Radio beacon block diagram.

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ANTENNA ASSEMBLY

AUX PULSER COIL

NORTH PULSER COIL

ANTENNA

TO & FROM CENTRAL ARRAY

DUMMY LOAD

J1156

P901 NORTH REFERENCE BURST TRIGGER

P902 AUXILLARY REFERENCE BURST TRIGGER

S6151 COAXIAL SWITCH

COAXIAL LINE

SA-420/URN-3 SWITCH TEST ADAPTER

RF OUTPUT

TO "PULSE ENVELOPE" JACK ON TS 891/URN-3 J6152

VIDEO OUTPUT TO MONITOR J6151

CR6152 DETECTOR

CR6151 DETECTOR

DIRECTIONAL COUPLER

VOLTAGE PROBE

J6153 J1155

CONTROL DUPLEXER

Z1153 RECEIVER PRE SELECTOR

Z1156 LOW BAND OR Z1157 HIGH BAND TRANSMISSION FILTER

DC1156 DIRECTIONAL COUPLER

DC1151 DIRECTIONAL COUPLER

J1153 REFLECTED J1154 INCIDENT

ANTENNA

J1152 REFLECTED J1157 INCIDENT

KLYSTRON OUTPUT

P921 J501

P922 J502

"LOCAL OSCILLATOR SIGNAL"

Z501 LOW PASS FILTER

P202 J202

HYBRID MIXER

G-1 V201, V202 & V203 PRE AMPL

P5 J203 P203

G-1 V301, V302 IF AMPL

P5 G1 V303, V304 V305 IF AMPL

P5 V306 FERRIS DISCR

P7 G2

V306A, V306B POSITIVE CLIPPERS

P5 G7 P7 G2

V307 VIDEO AMPL

P3 P6

V409A DC CLAMP

V407A DC REGULATOR

V409B PULSE COUNTER

SQUITTER VOLTAGE

SQUITTER ADJUST

20V

10.4μS   10.4μS

KLYSTRON INPUT

REFLECTED INCIDENT J1408 J1409

DC1401 DIRECTIONAL COUPLER

9V

10μS

L8V

10 μS

V1401

V1401, V1408 ONE SHOT MV

P1,9 P1,6 G2,7 G2,7

V1409 AMPL

3.5μS 10μS

M1301

Z1303 DOUBLE-SLUG TUNER

V1304 POWER AMPL (SAL-89)

J1309 P915 P920

J1407

V1506 KEYED RF AMPL

K G V1505 KEYED RF AMPL

G V1504 TRIPPLER

G V1503 3RD DOUBLER

K2

KLYSTRON

900V 3.5μS   1500V 3μS   2300V 3μS

J1370 P913 P916

J1402

K1,4,6 V1407 V1411 CATHODE FOLLOWER

G5 V1406 SERIES DIODE

K CAP P2,7 P CAP

V1403 V1404 V1405 POWER AMPL

G5

10V

4.3 μS

J1405 SHAPED PULSE

FREQUENCY MULTIPLIER OSCILLATOR CV

TRANSMITTER SECTION OF RADIO SETS AI

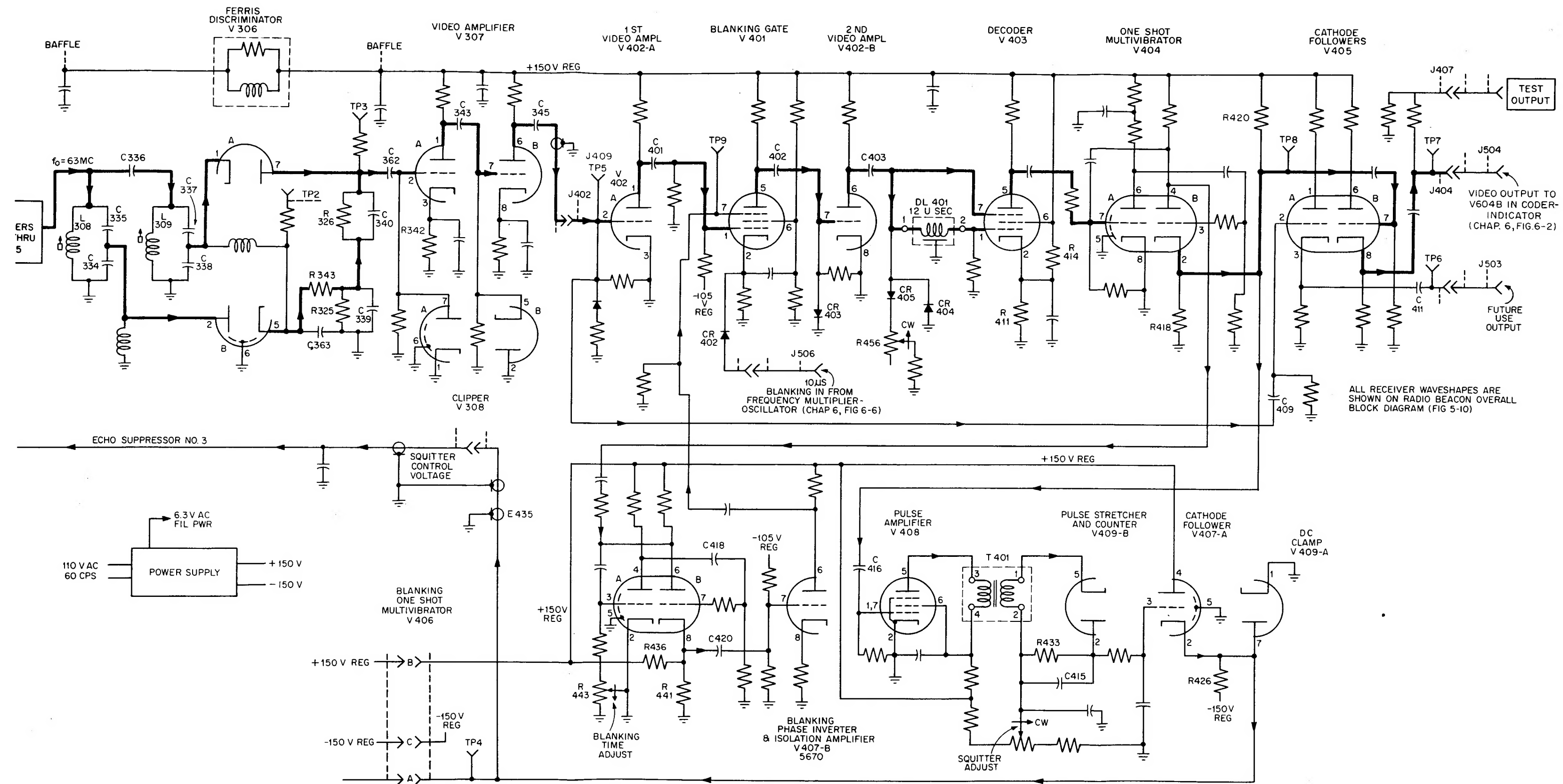Figure 5-18.—I-f amplifier, video, and decoder stages.

32.89

DOD DIR 5200.10

CONFIDENTIAL

1ST IF
AMPLIFIER
V 301

FERRIS
DISCRIMINATOR
V 306

VIDEO AMPLIFIER
V 307

1 ST
VIDEO AMPL
V 402-A

BAFFLE

BAFFLE

+150 V REG

J204
+150 V
REG

J203

f₀=63MC
L 302

f₀=60.7MC

f₀=63MC

C336

C
337

IF
AMPLIFIERS
V 302 THRU
V 305

C
304

L
301

C
302

L
303

C
308

L
309

C
334

C
335

C
338

TP2

R
326

C
340

A

B

C
362

R342

TP3

C
343

C
345

V
402
A

J409
TP5

C
401

J402

R343

R325

C
363

C
339

INPUT FROM
PREAMPLIFIER V203,
FIG 5-16

CLIPPER
V 308

ECHO SUPPRESSOR NO. 3

SQUITTER
CONTROL
VOLTAGE

E 435

6.3 V AC
FIL PWR

110 V AC
60 CPS

POWER SUPPLY

+150 V

−150 V

BLANKING
ONE SHOT
MULTIVIBRATOR
V 406

+150V
REG

R436

+150 V REG

B

R
443

R
441

−150 V REG

C

−150 V
REG

TP4

BLANKING
TIME
ADJUST

A